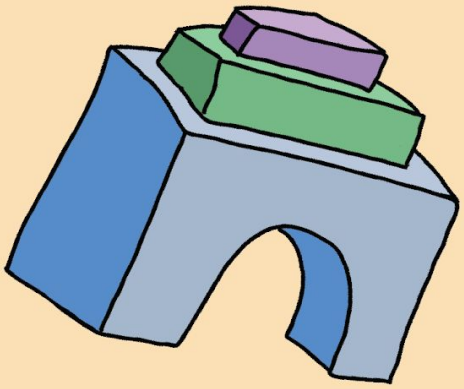

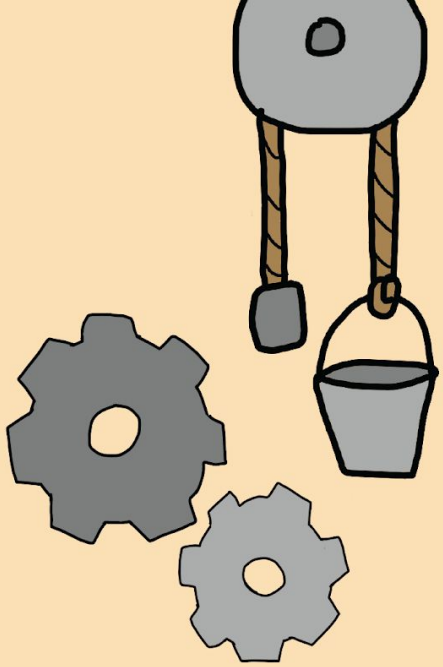

CONSTRUCTOPEDIA

VERSION 2.0

PLAYFUL ENGINEERING-BASED LEARNING

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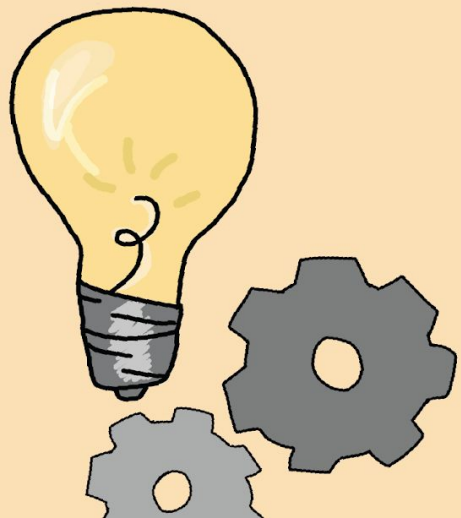

Created by

Anne Hu
Richie Ng
Kat Guzman
Joao Medeiros
Andy Wu
Sophie Hankin

Funding provided by
The LEGO Foundation
for the
Playful Engineering-Based Learning project.

V2.0
2023

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Table of Contents

How to use the constructopedia

This is your guide to building small things so that you can build bigger things!

1. Look at the Table of Contents to find instructions

2. Gather your materials, which are always outlined in pink boxes

3. Follow the instructions in the blue boxes to build your mechanism

Mechanism: Smaller part that works to make a more useful, larger part.

4. Use your basic mechanism in your bigger project!

Let's get building!

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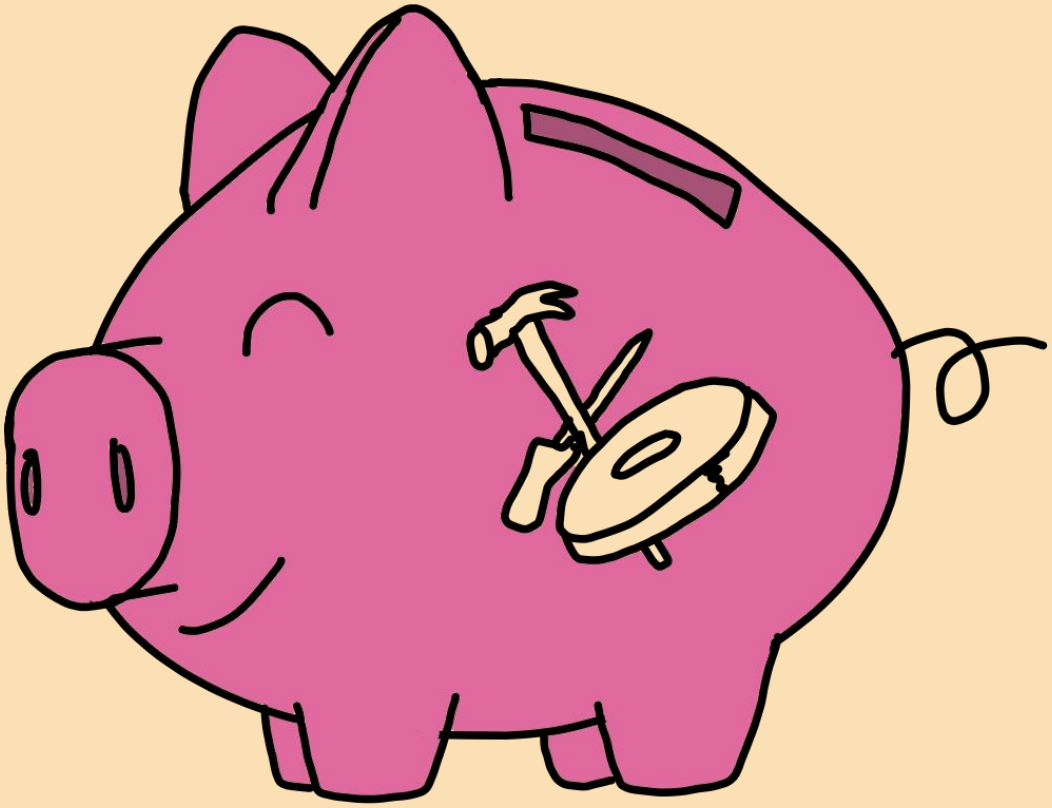
Material bank



What you need to make the things.

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Construction materials

Long and thin things

Popsicle stick

Toothpick

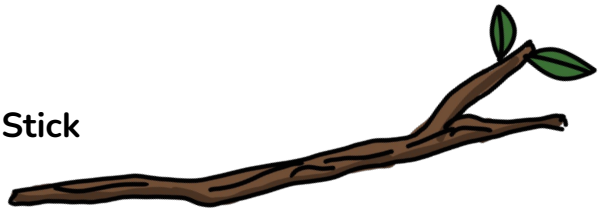
Straw

Marker

Pencil

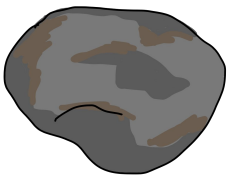
Wooden dowel/skewer

Stick



Chopstick

Miscellaneous

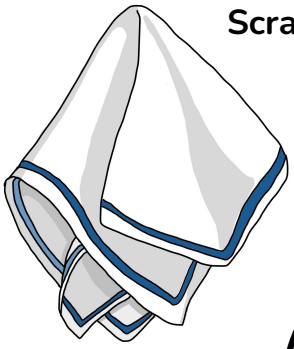


Rock

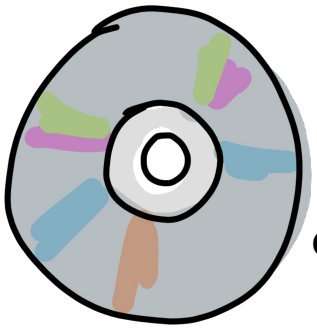
Pushpin

Bottlecap

Scrap fabric



Clay



CD

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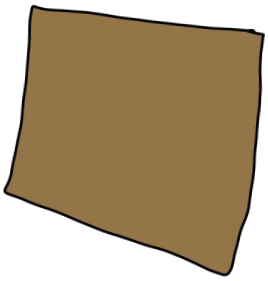
Construction materials

Paper-based things

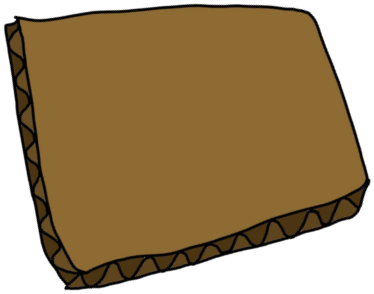
cereal box cardboard



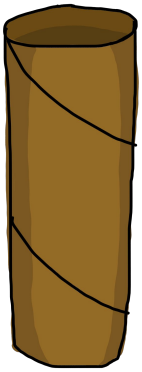
paper cup

scratch paper

corrugated cardboard

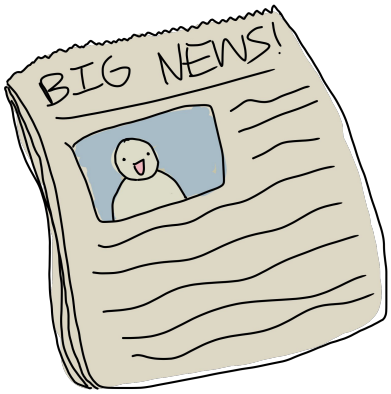


paper tube

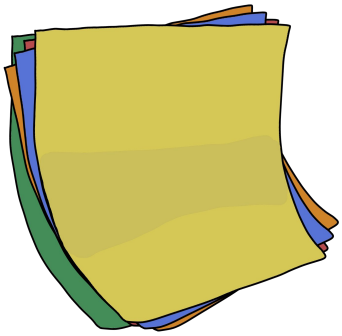


cardstock paper

newspaper



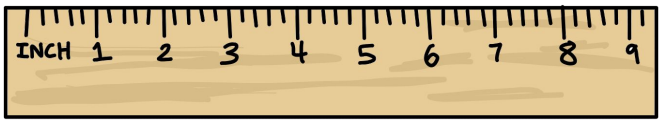
colored paper



Other Tools

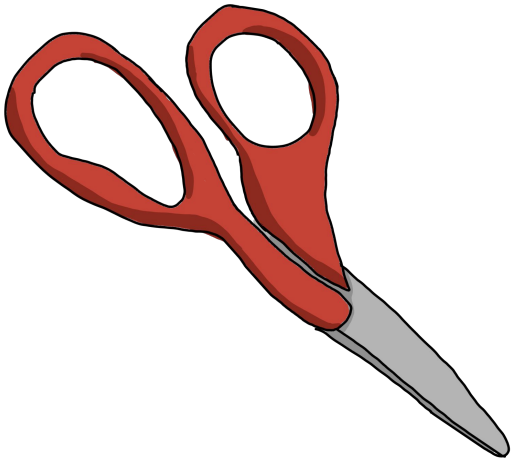
pen

ruler

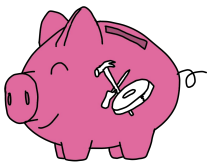


cutting knife

scissors

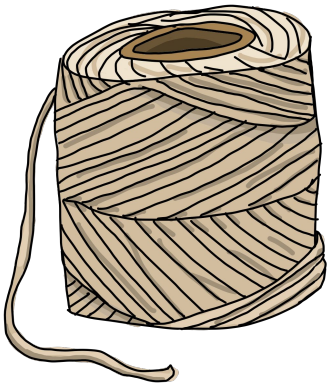


Connecting materials



liquid glue

string

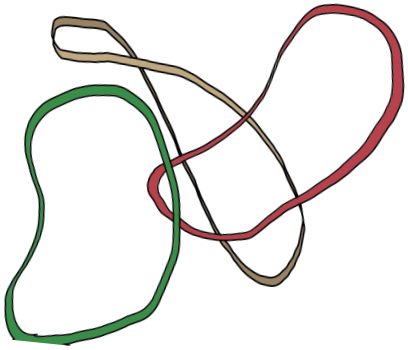


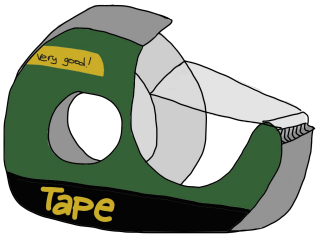
safety pin

clear tape

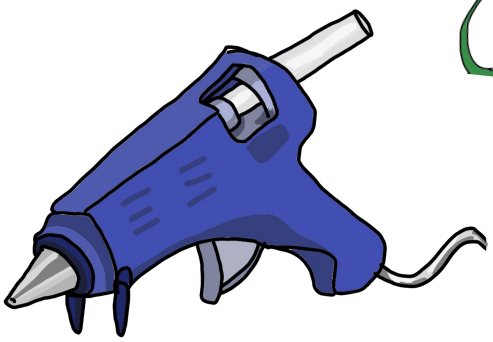
masking tape

rubber bands





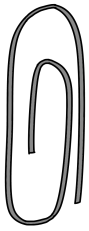
hot glue gun

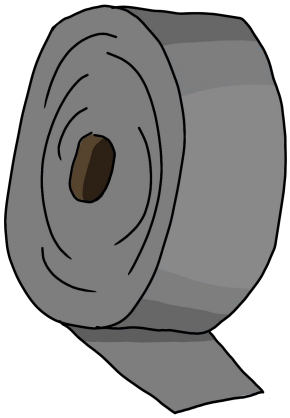


pipe cleaner

duct tape

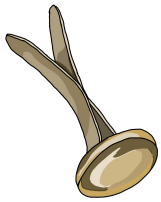
paper clip





binder clip

brad



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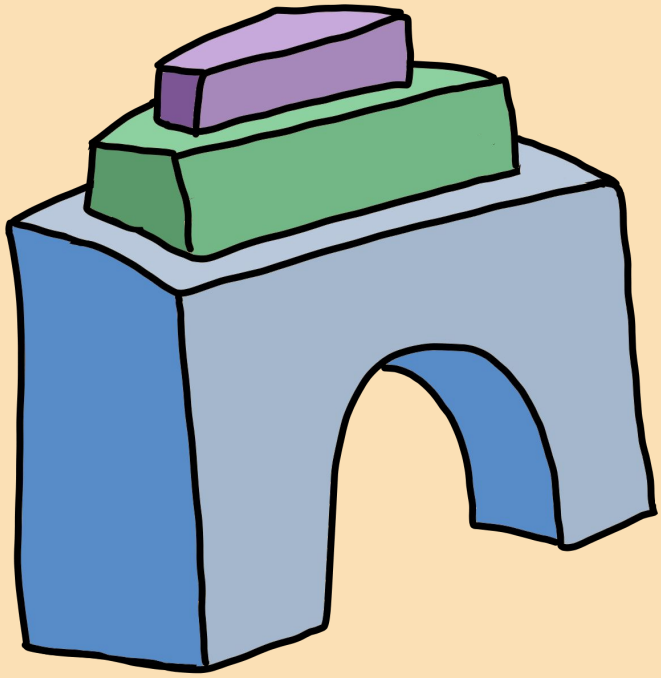
NEWS!


NEWS!

Structures



Get ideas for building basic structures!

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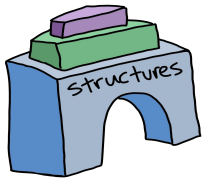
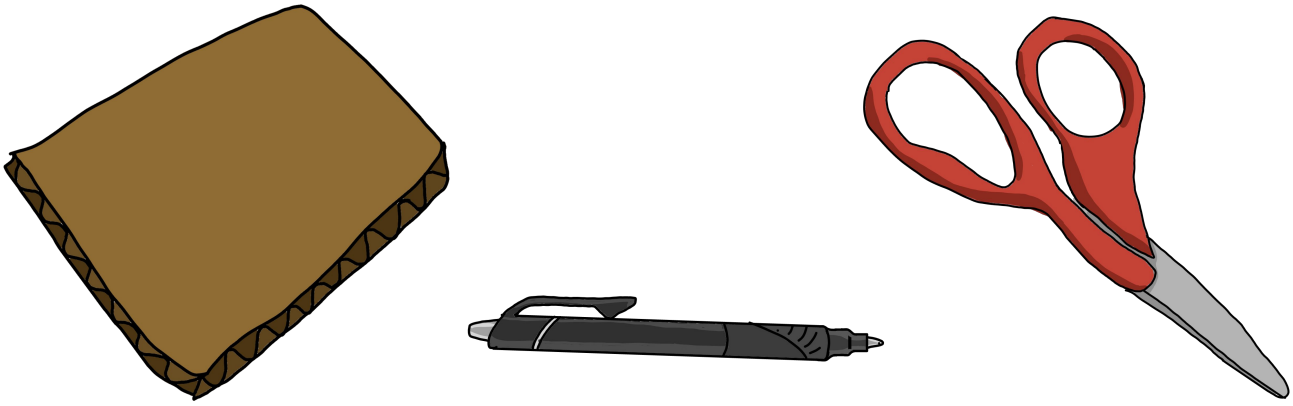
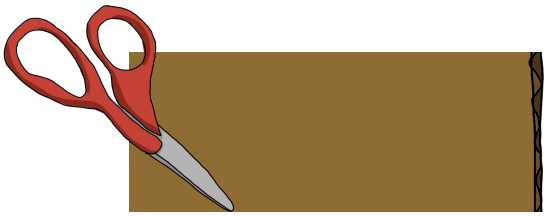
Cardboard ramp





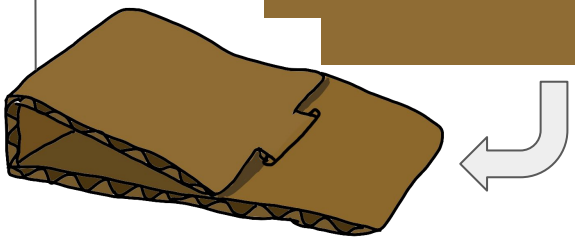
Step 1: Cut a long rectangle out of cardboard.



Step 2: Cut a tab on one end of the cardboard.

Step 3: Fold to desired ramp height and mark the edges of your tab. Unfold.

Step 4: Cut out a small rectangle where you marked the tab, then re-fold and tuck the tab into the hole.



To make the ramp smooth, add a piece of cardboard or paper over the ramp.

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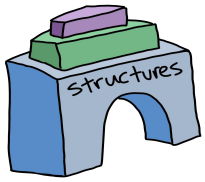
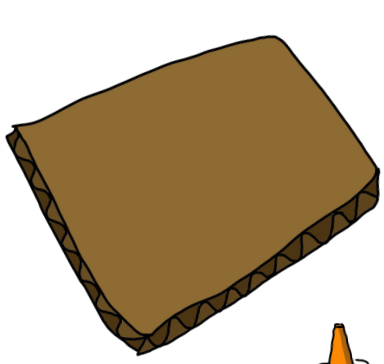
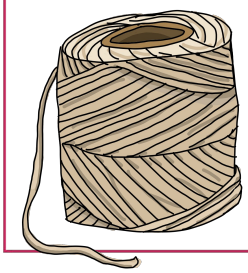
See how it rolls!

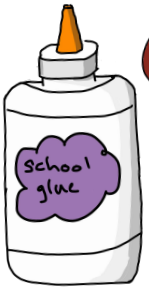
Popsicle ramp

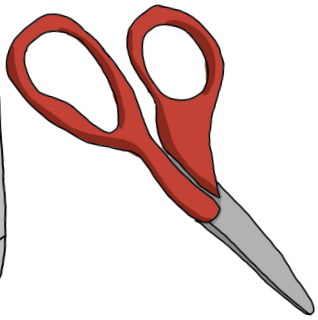




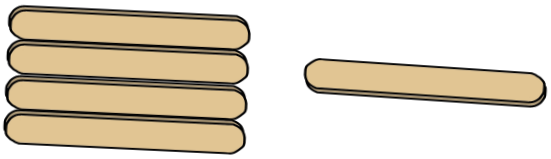
x4 or more



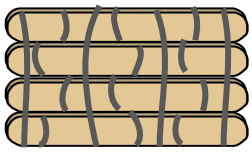




Step 1: Set one popsicle stick aside, then put the other popsicle sticks side to side.

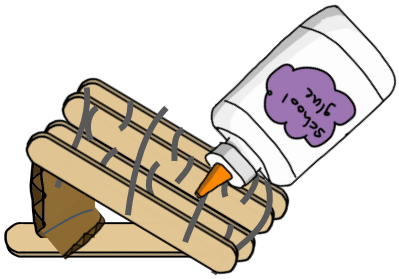


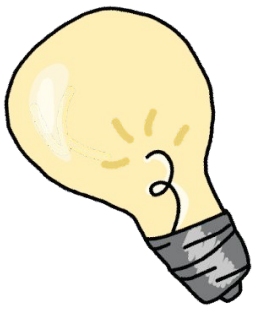
Step 2: Weave string through the popsicle sticks to tie them together.



Step 3: Fold the cardboard at both ends to create small flaps. Glue one flap to the ramp, and the other flap to the last popsicle stick.

Glue the last popsicle stick to the base of the ramp.





Use hot glue for a sturdier ramp.

Experiment with different ways to connect the popsicle sticks!

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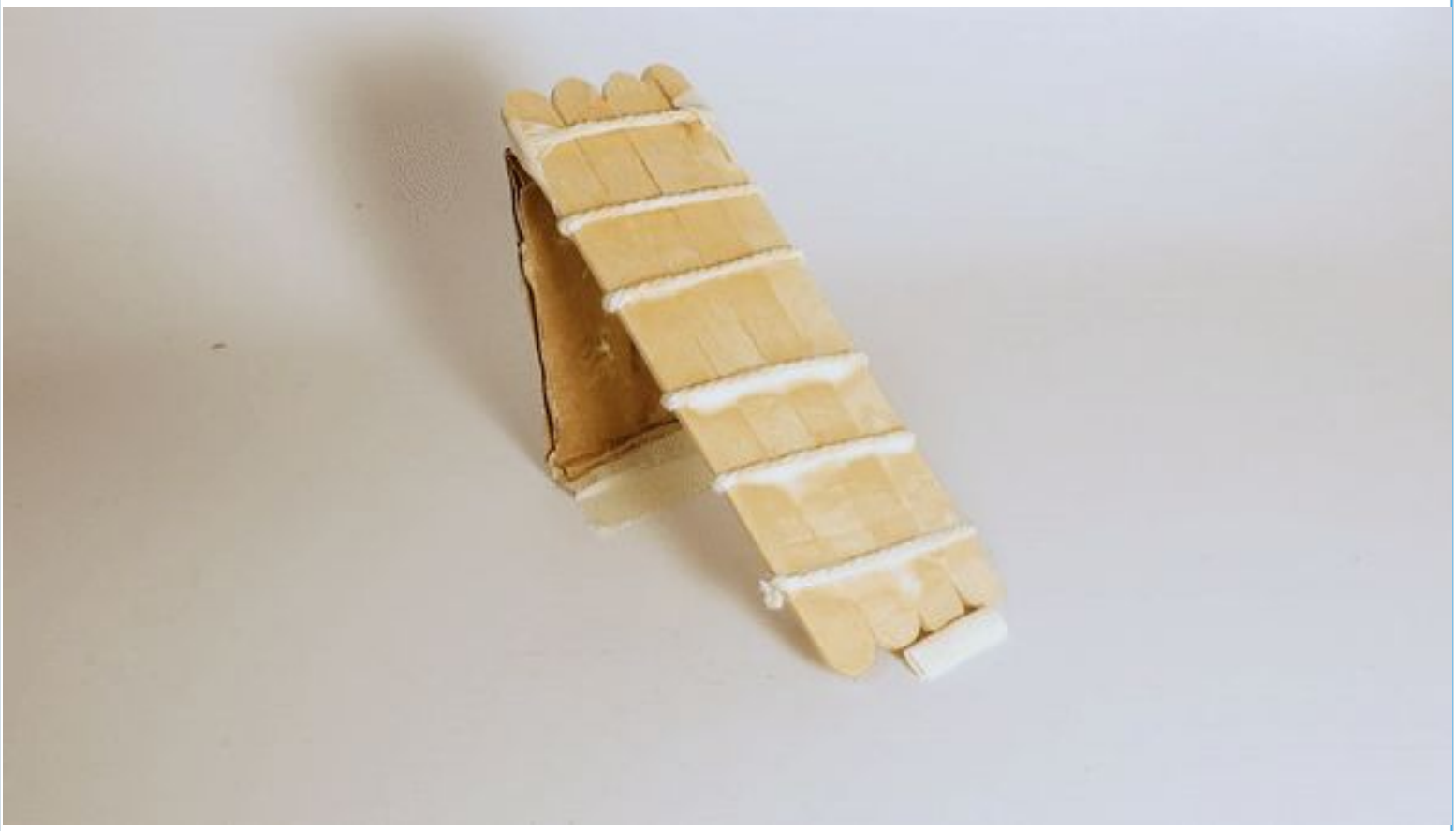
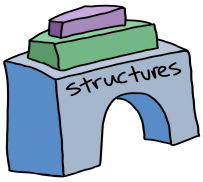
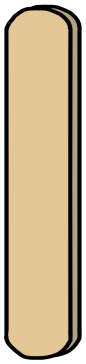
See how it rolls!



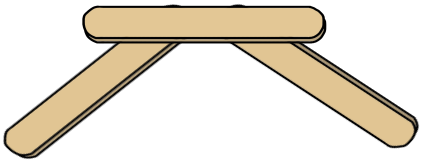
Popsicle chair legs



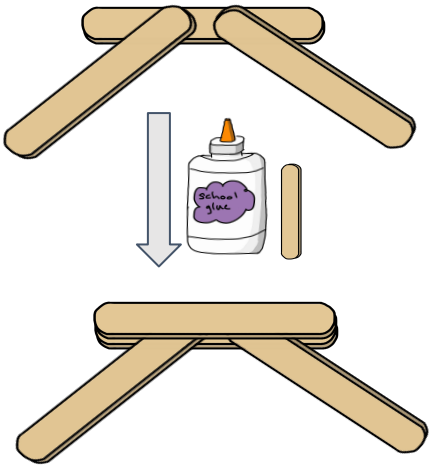


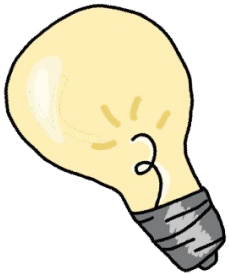
x4

Step 1: Make a triangle out of 3 popsicle sticks. Glue together and let dry.

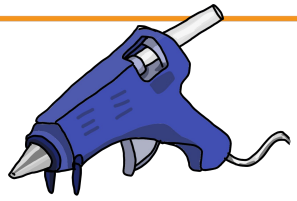


Step 2: Flip over, and glue another popsicle stick at the top.

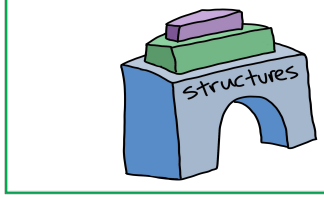


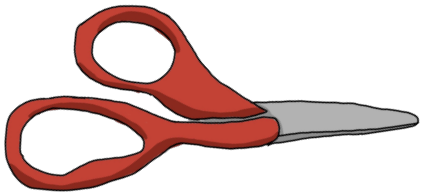


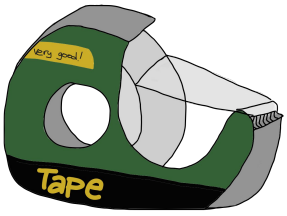
Let the glue dry completely in each step! Hot glue dries faster and is stronger.

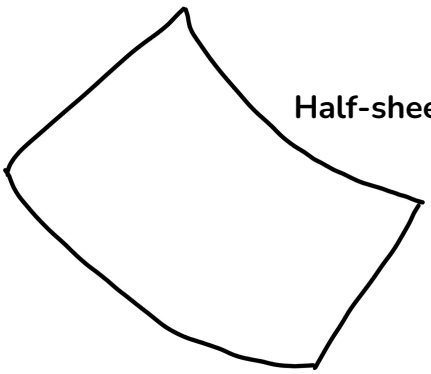


Cardstock chair legs



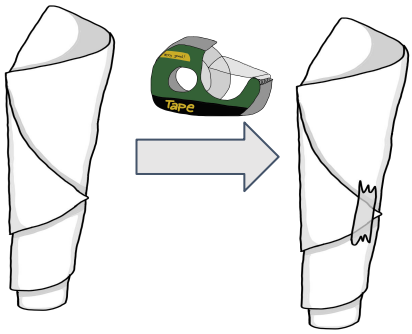




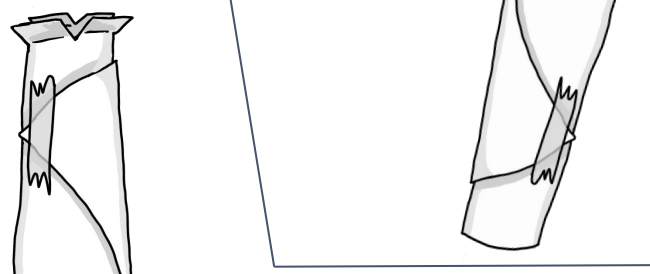


Half-sheet of cardstock

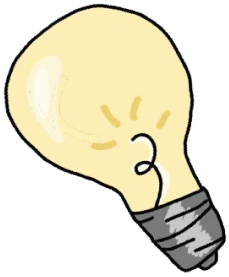
Step 1: Roll the paper into a cone. Tape.



Step 2: Cut both ends flat and then cut to desired height.

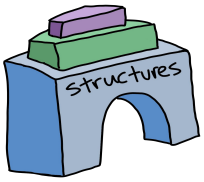


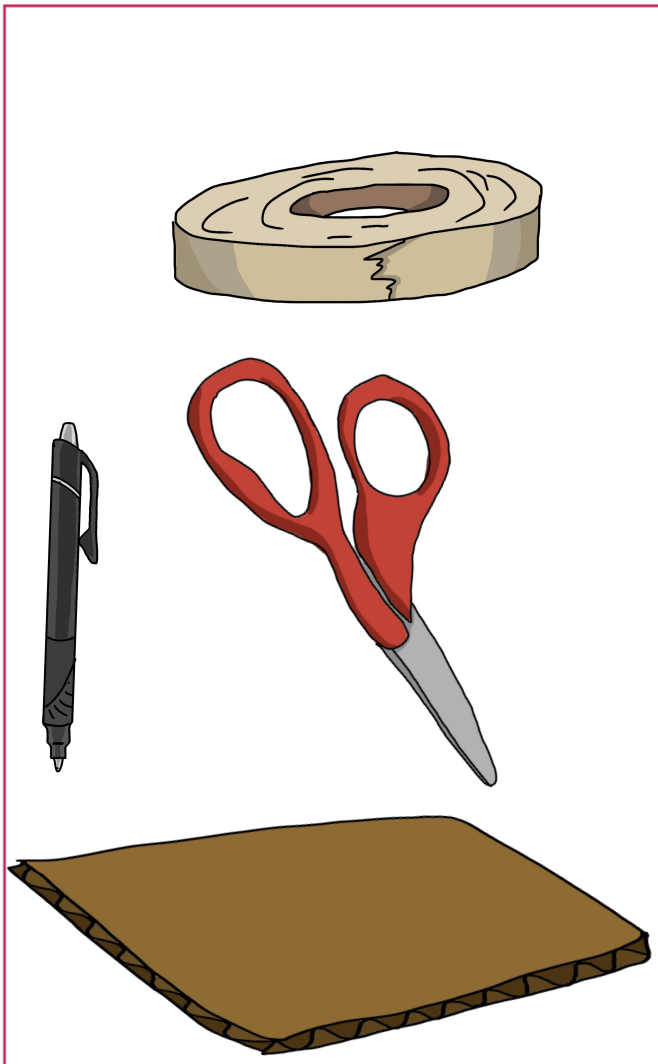
Step 3: Flip. Cut 4 shallow slits in the top of the funnel. Flatten to make tabs.

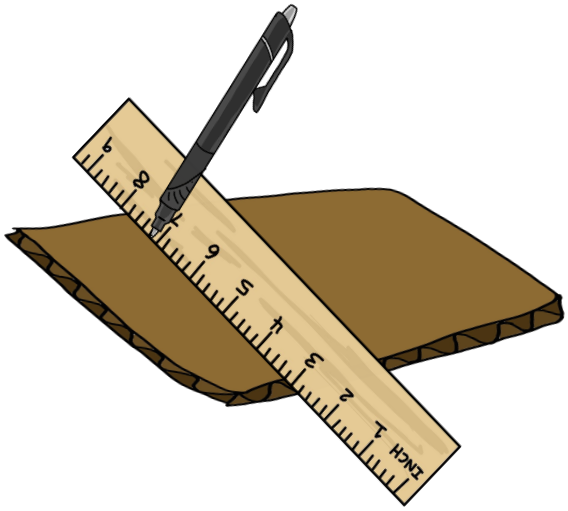


Connect the chair legs to a flat surface by taping the tabs on.

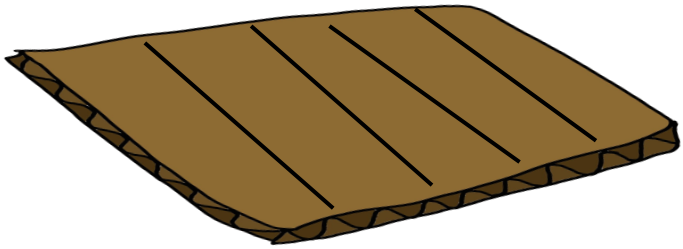
Cardboard pillars

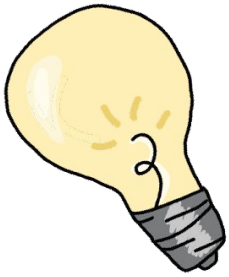






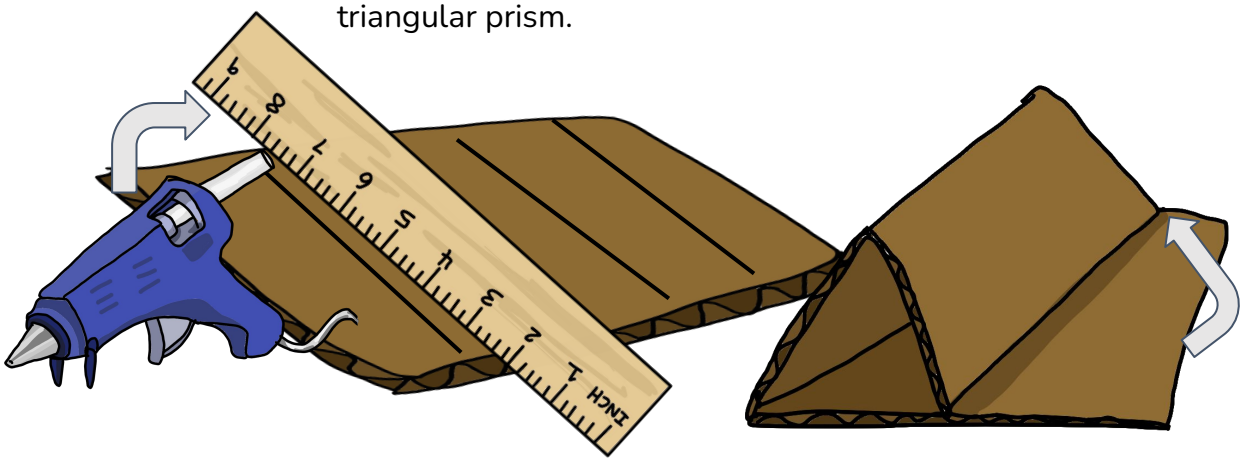
Step 1: Draw 4 even, straight lines on the long side of the cardboard.

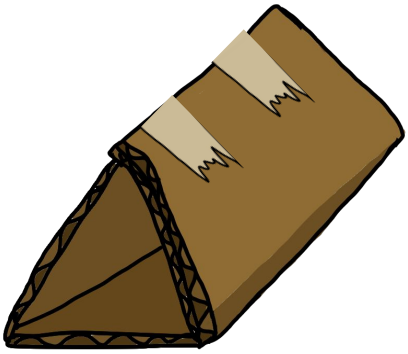




Use a long rectangular piece of cardboard for a easier folding!

Step 2: Use a ruler to fold along the lines, curling the cardboard into a triangular prism.

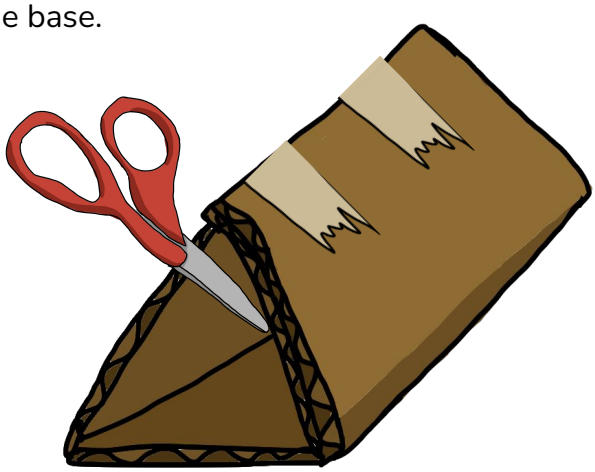




Step 3: Secure with tape.

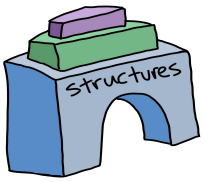
Step 4: Cut off any uneven paper on the base.

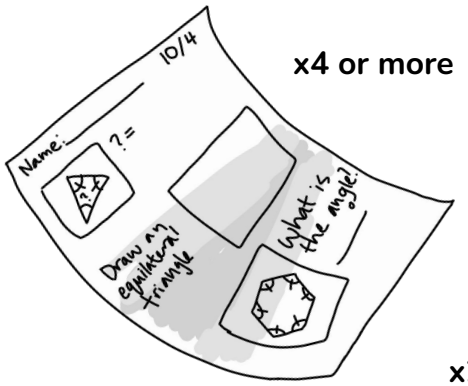
Your pillar should stand on the triangle face as the base.



Sturdy pillar with a 1.5kg water bottle on top

Paper pillars

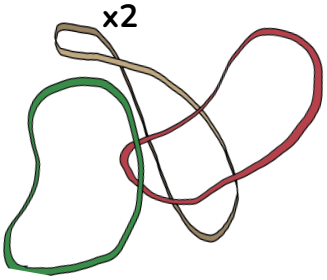




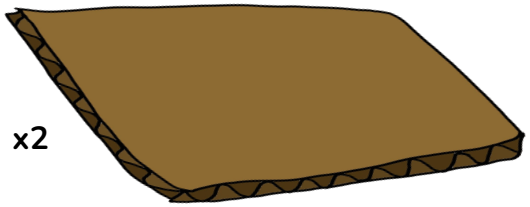
x4 or more

x2 per paper

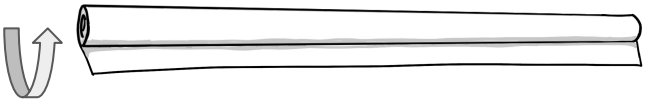
x2

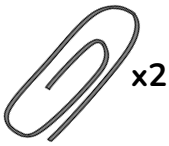


x2

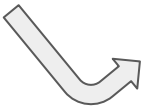


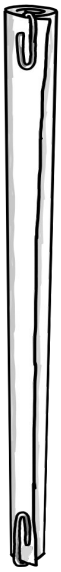
Step 1: Tightly roll scratch paper. Paper clip both ends.



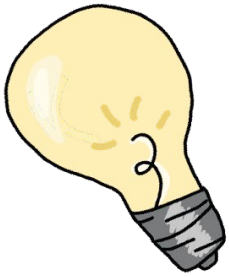


x2



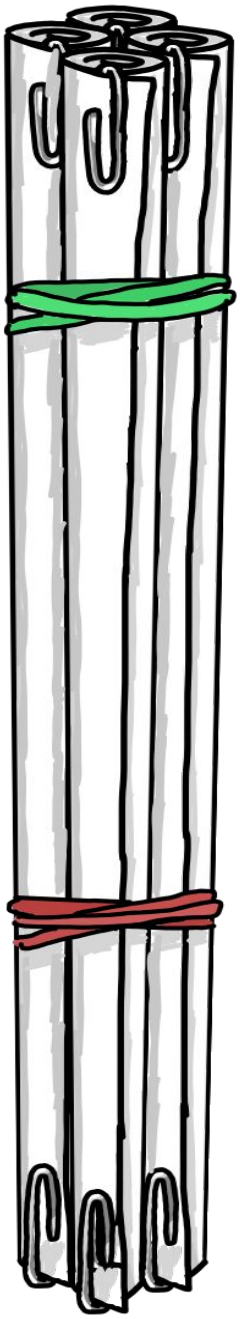


x4 or more

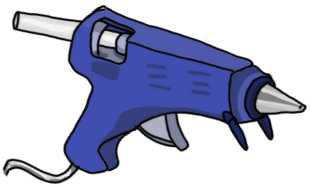


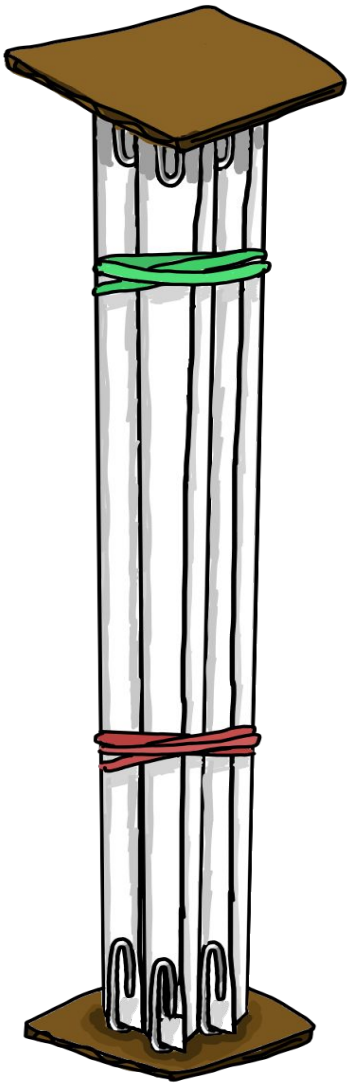
Use more rolls of paper for a sturdier pillar.

Step 2: Rubber band the rolls of paper together.

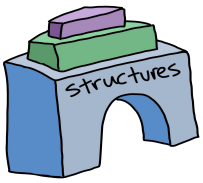


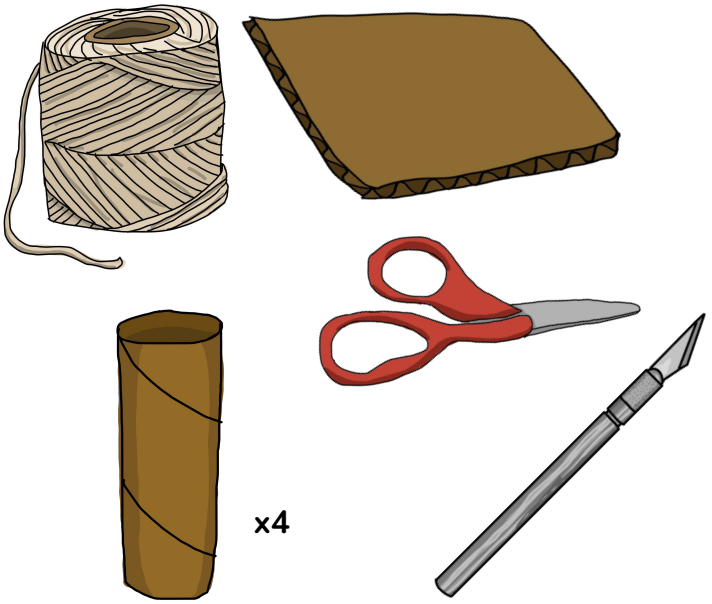
Step 3: Glue a small piece of cardboard on the top and bottom.



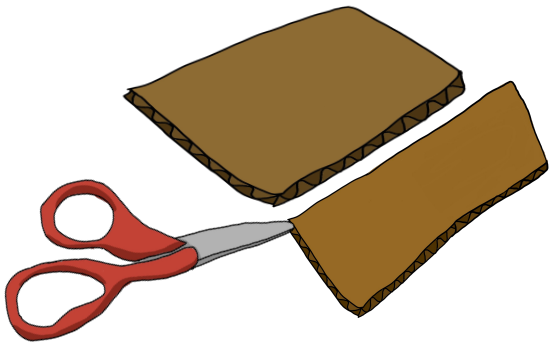


Suspended bridge

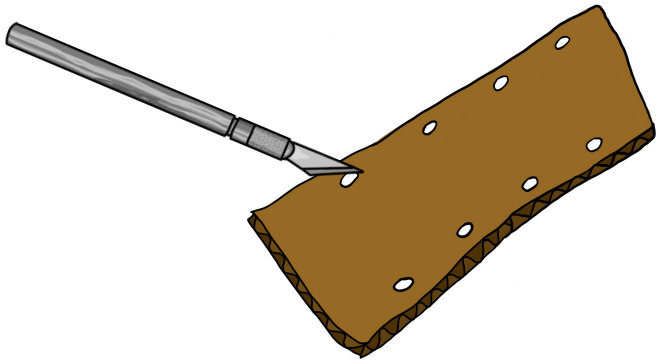




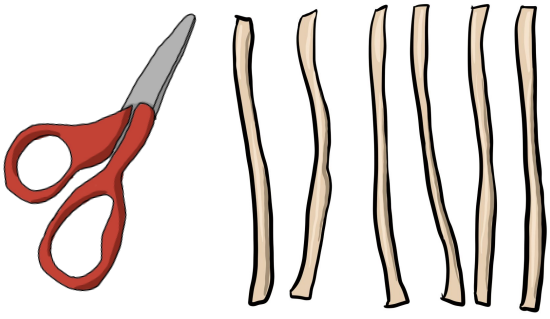
Step 1: Cut cardboard into long rectangle

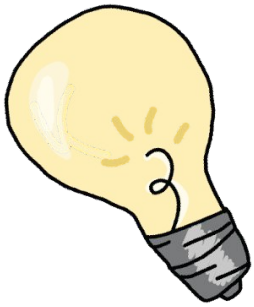


Step 2: Cut evenly spaced holes along both sides of the cardboard with the X-ACTO knife.



Step 3: Cut out as many 3-4 inch pieces of string as there are holes.





For Step 1: the more holes you cut, the stronger the structure will be. Be sure not to cut the holes too close to each other to prevent ripping.

Have an adult help with the X-ACTO knife!

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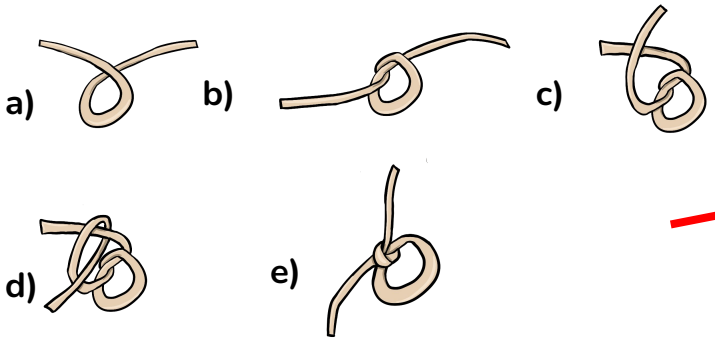
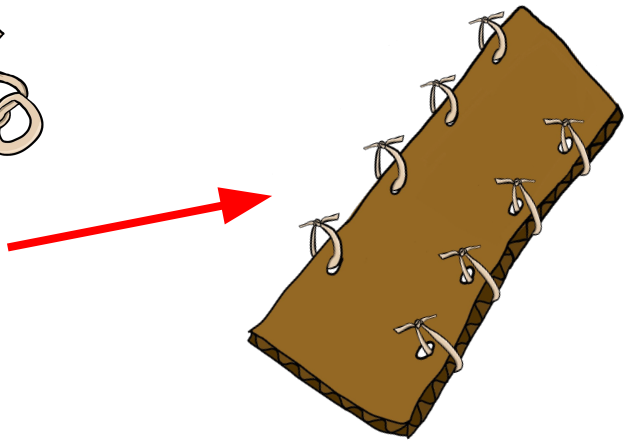
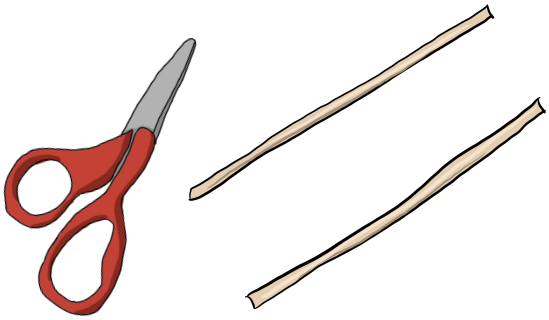
Step 4: Loop each string into a small circle through each hole and knot it on top of the loop as shown below.

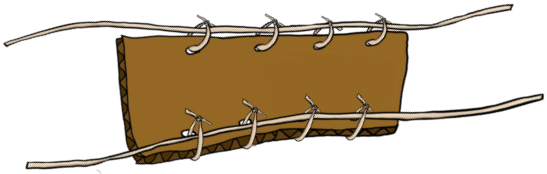




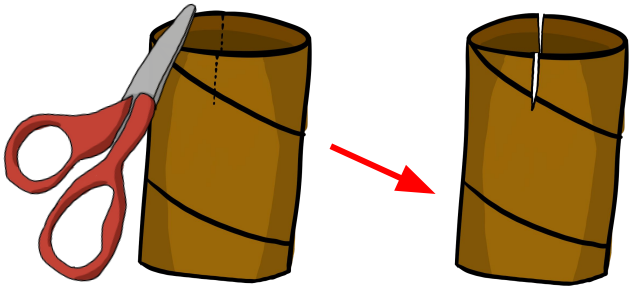
Step 5: Cut two pieces of string that is each around 5 inches longer than your cardboard.



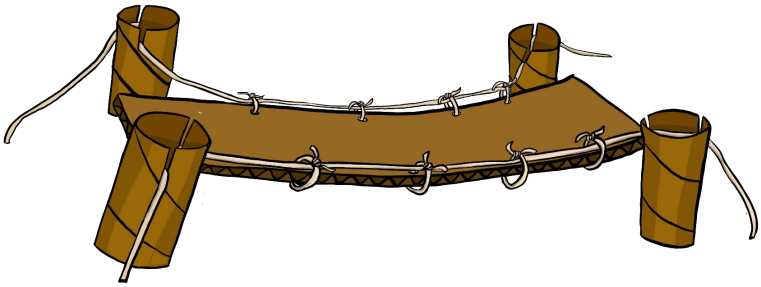
Step 6: Pull each string through all the loops on each side.



Step 7: Make 2 cuts 1-2 inch deep on all the paper tubes as shown.



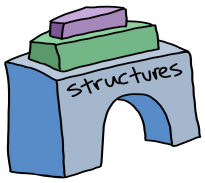
Step 8: Put each end of the string through the cuts like shown below.

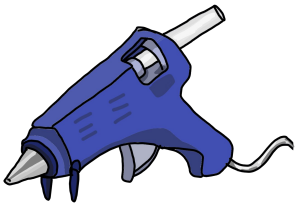


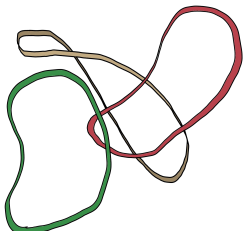
How to tie bridge knot:

See the bridge in action!

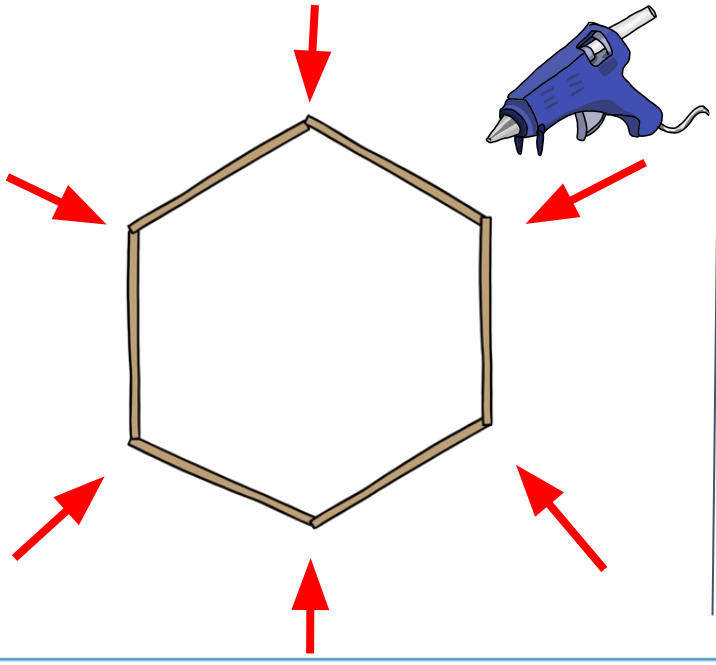
Trampoline



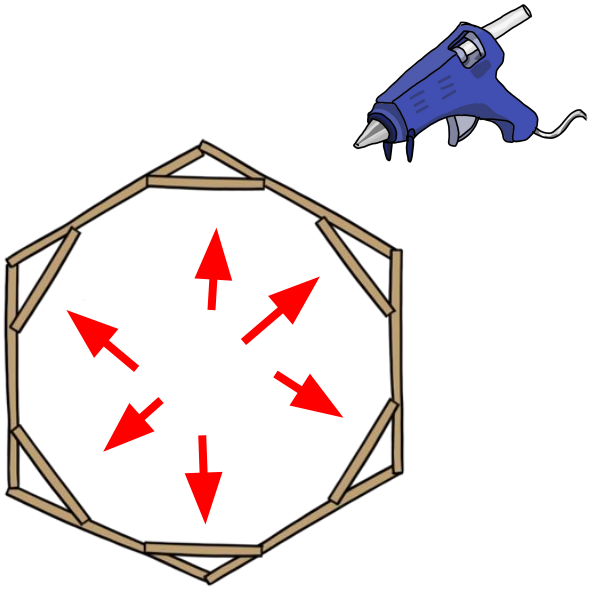




Step 1: Assemble the popsicle sticks to form a circular frame and hot glue gun the popsicles into place.



Step 2: Assemble another set of half popsicle sticks inside the frame you already have so it looks like below. Glue together.



For Steps 1 and 2, you can use tape instead of glue!

For Steps 4 you can tie an extra rubber band in between if the two rubber bands can't reach each other!

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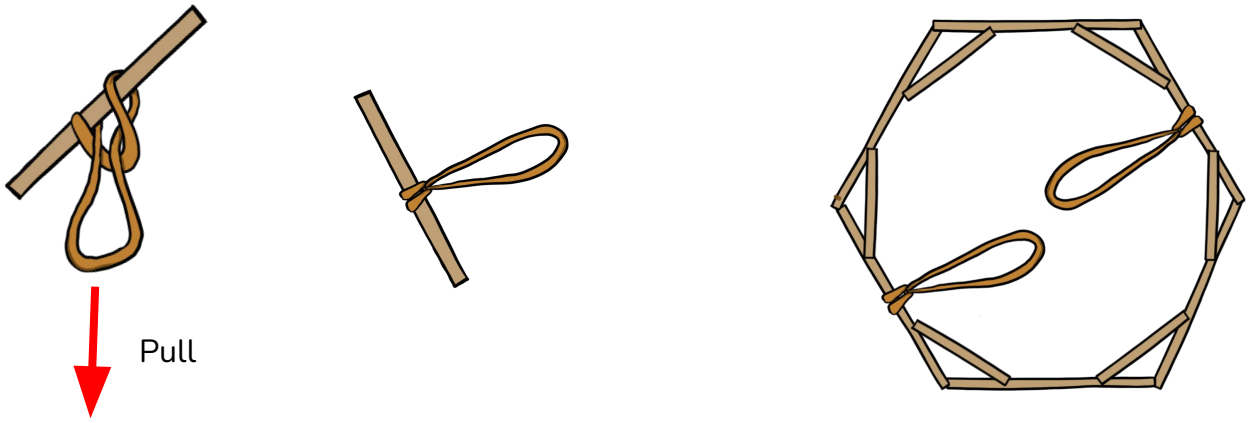
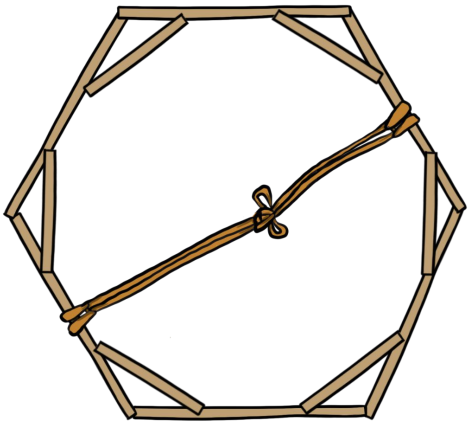
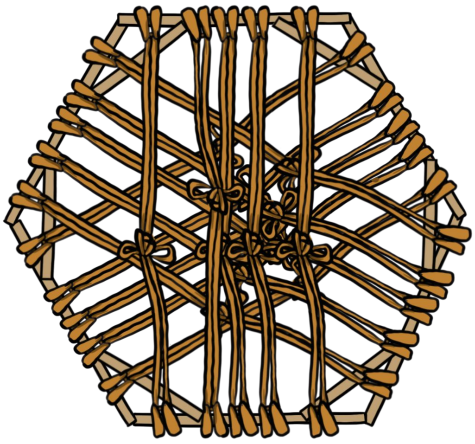
Step 3: Loop a rubber band on the frame then do the same on the opposite side of the frame



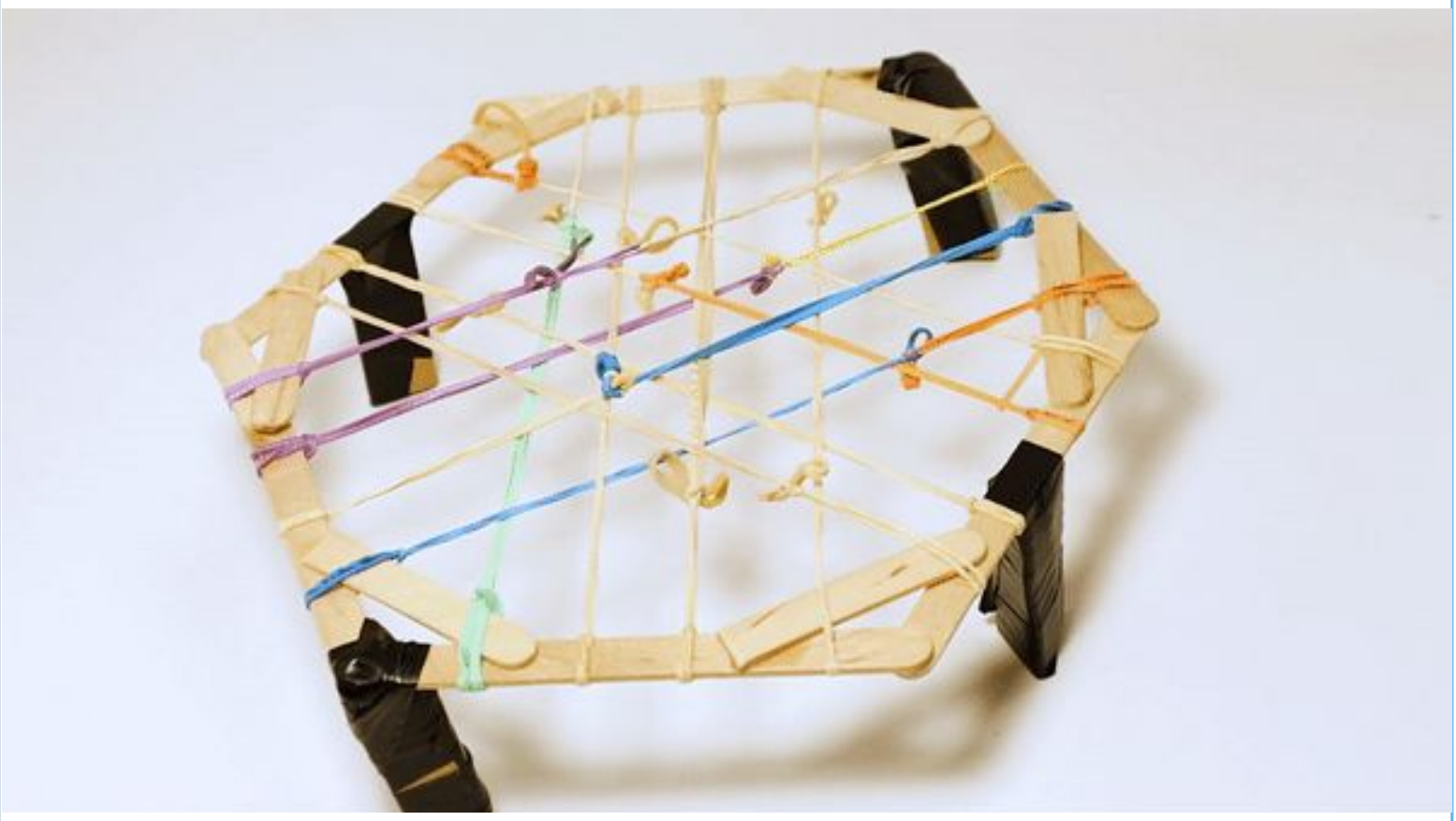
Step 3: Tie two rubber band together in a knot



Step 3: Repeat steps 3 and 4 until you fill up the frame

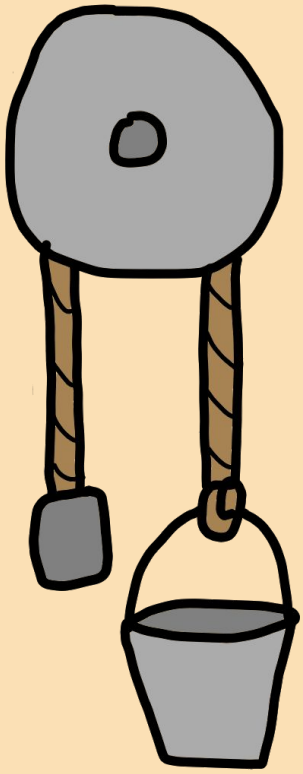


Watch it bounce!




NEWS!

Lifting mechanisms



Learn to lift heavy loads!

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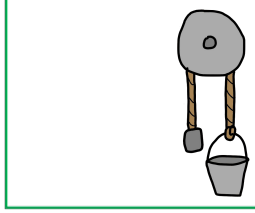
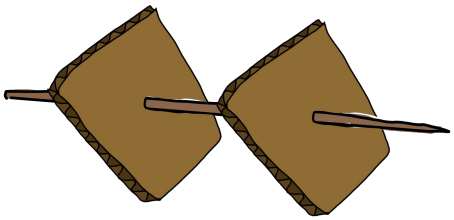
Pulley option 1

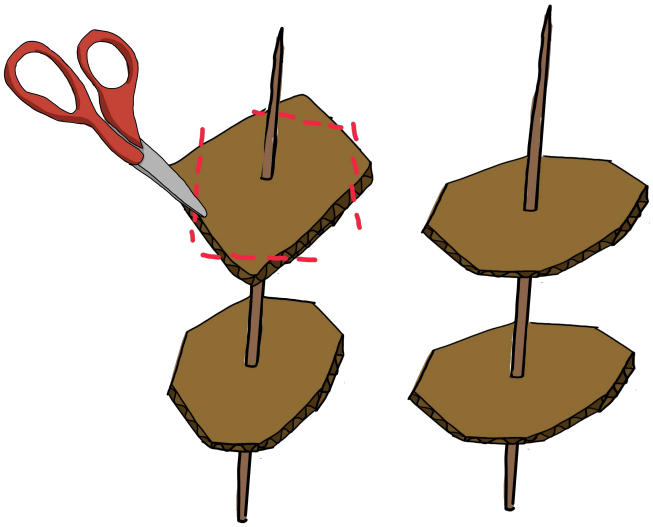


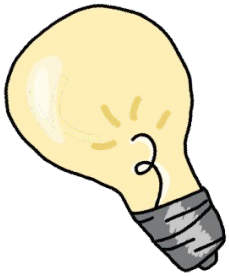
x2, same size

Step 1: Use the skewer to poke through the center of each piece of cardboard.



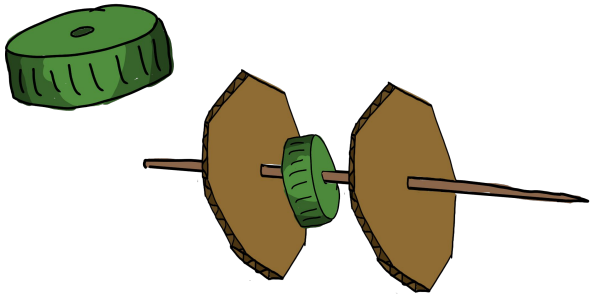
Step 2: Cut the corners off of the cardboard, making a hexagonal shape.



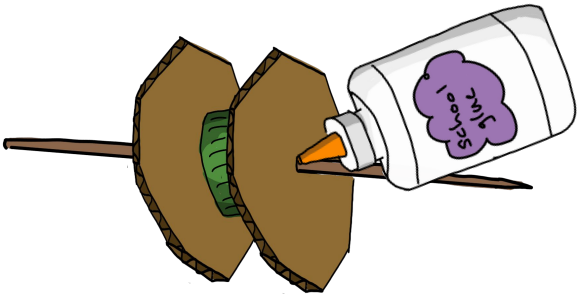


Any cylindrical object can replace the bottle cap.

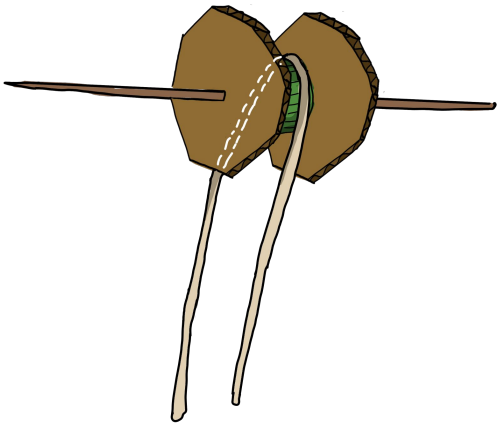
Step 3: With the help of an adult, poke a hole through the center of the bottle cap.



Step 4: Push the cardboard and bottle cap to the center of the skewer, "sandwiching" the bottle cap. Glue together.

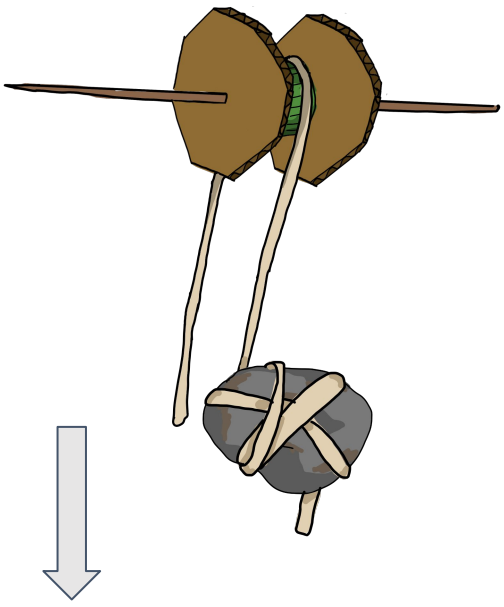


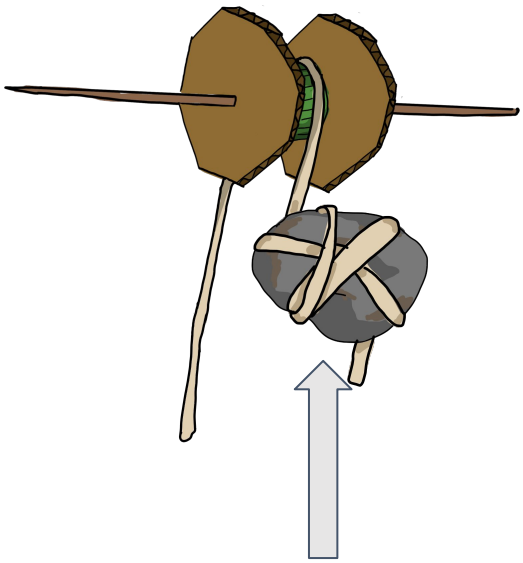
Step 5: Cut a piece of string and drape over the bottle cap.



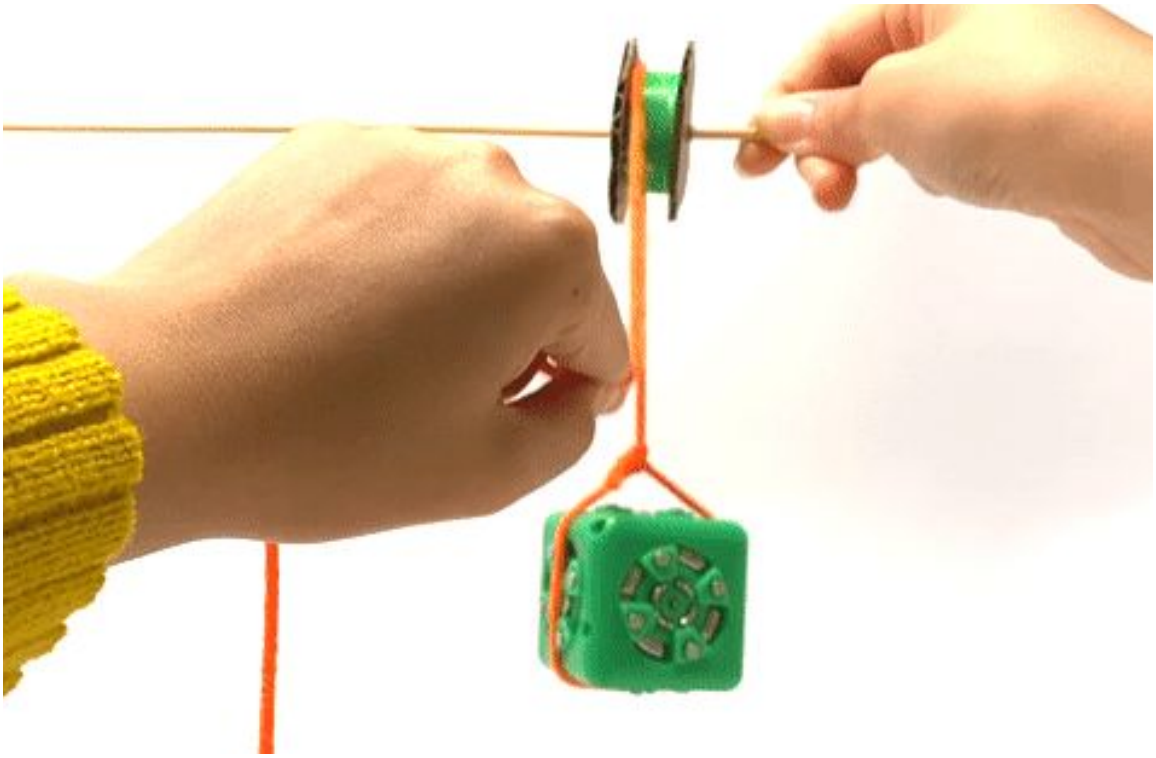
Step 6: Tie one end of the string to the object you want to lift.

Pull down on the other side of the string to lift!

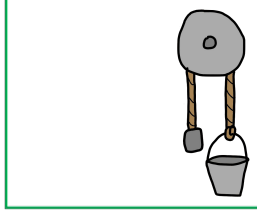


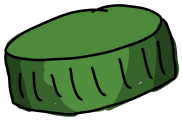


Watch the pulley in action!

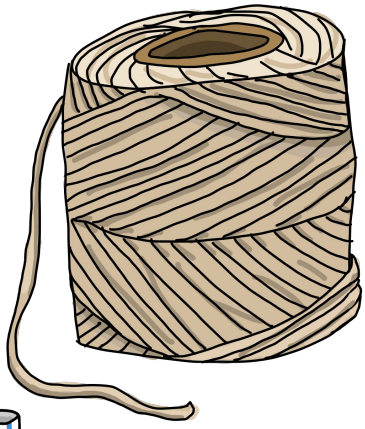


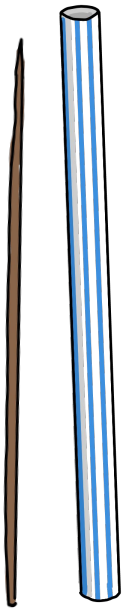
Pulley option 2

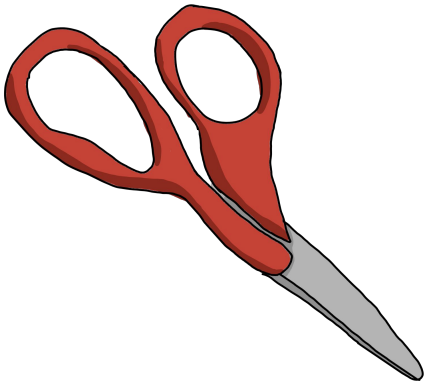




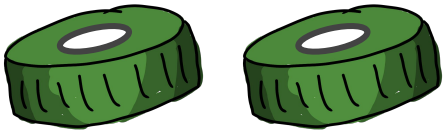
x2, same size



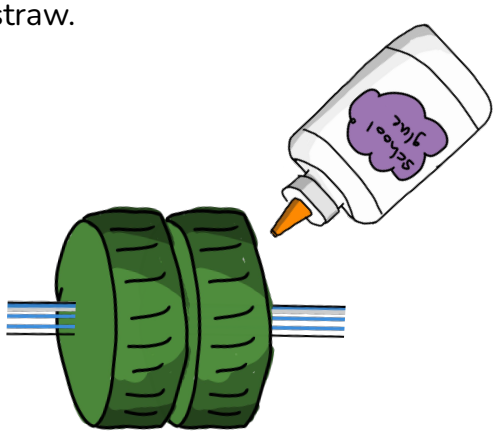


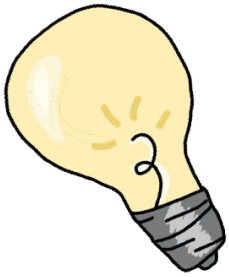


Step 1: With the help of an adult, cut a hole for the straw through each bottle cap.



Step 2: Glue the bottle caps together, then insert the straw.

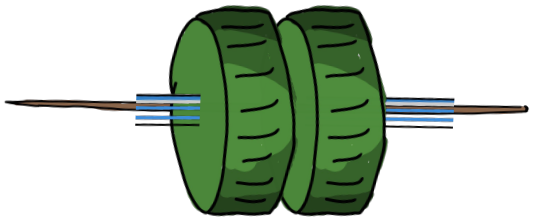




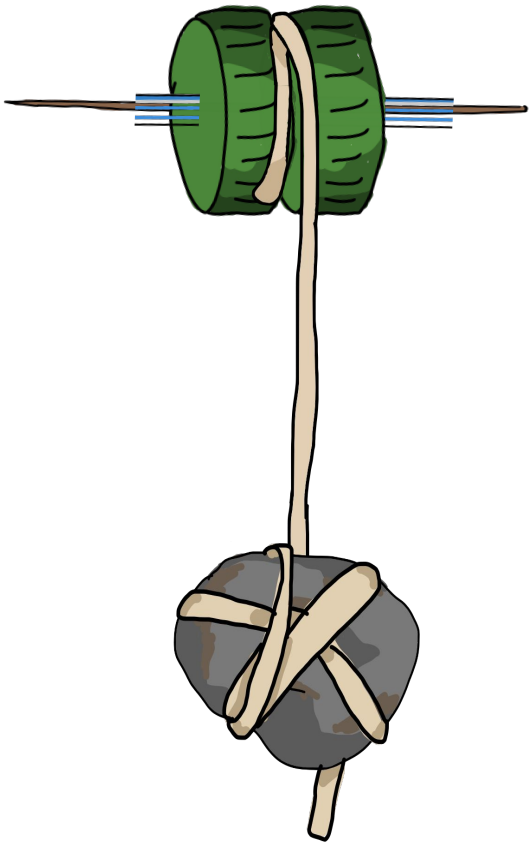
The skewer should be longer than the straw. You may cut the straw smaller.

Save straw scraps for future projects!

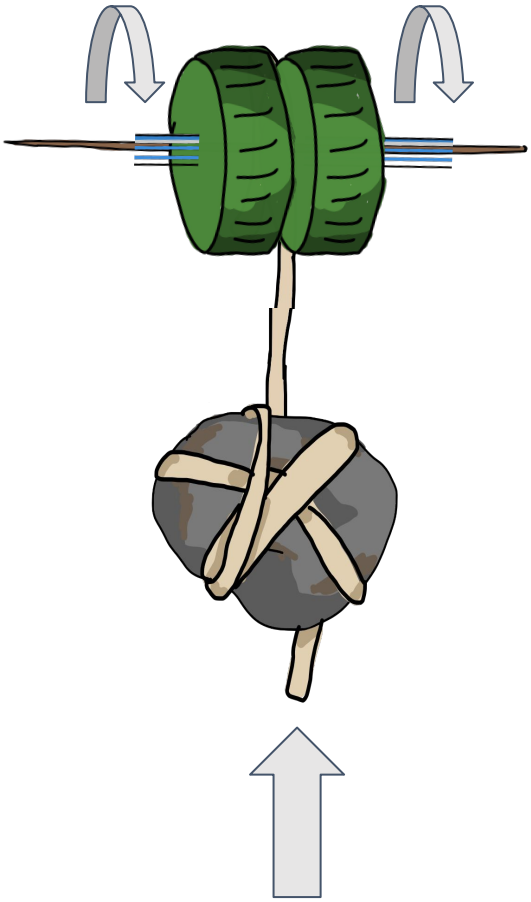
Step 3: Insert the dowel through the straw.



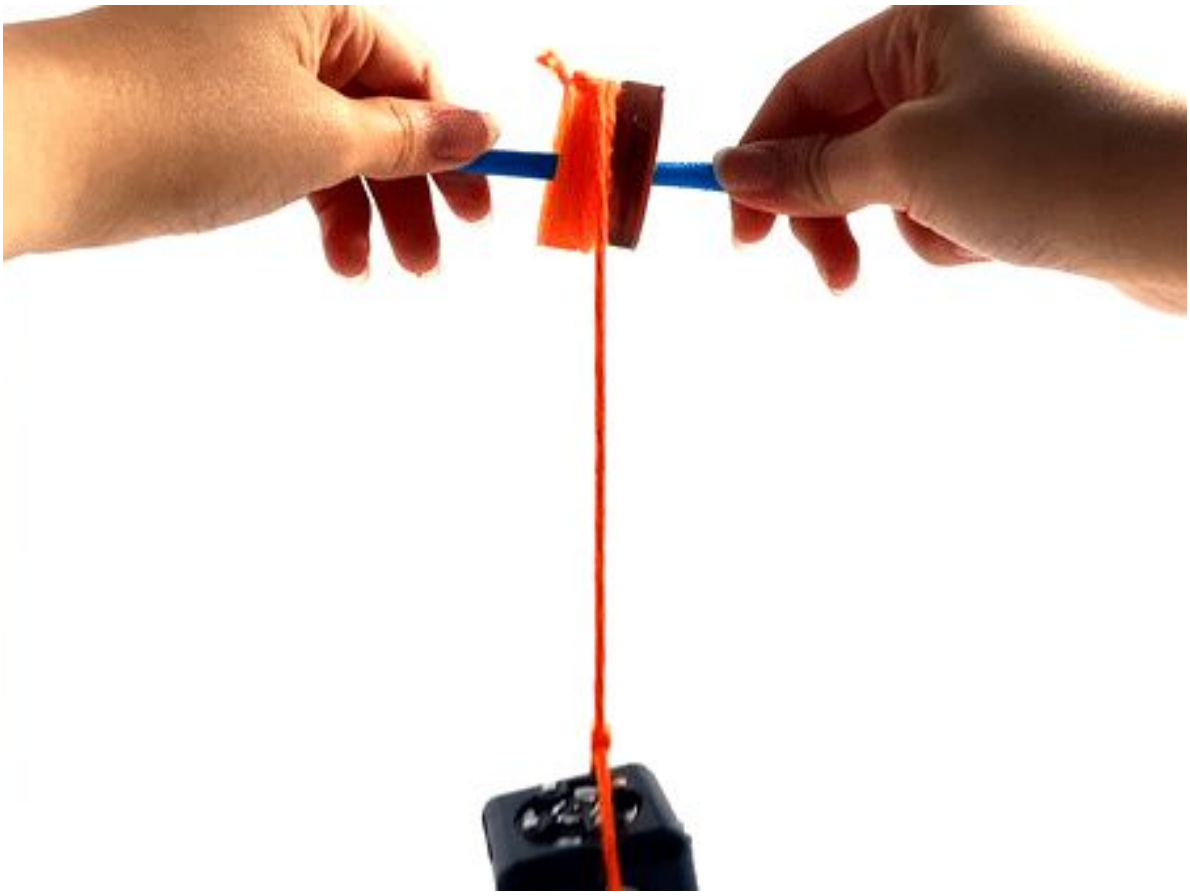
Step 4: Tie one end of the string around the middle of the two caps. Tie the other side to the object you want to lift.



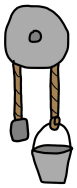
Step 5: Spin the bottle caps to lift the object.

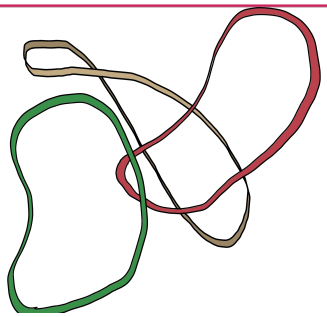


Watch the pulley in action!

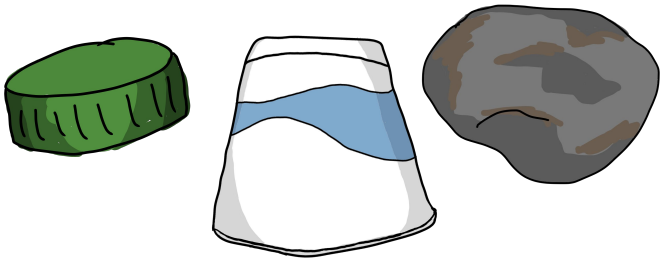


LEVERS

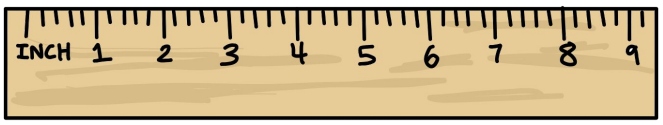




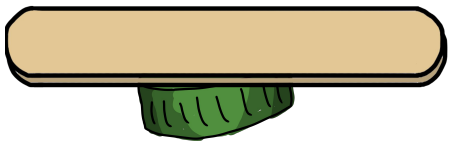
For the fulcrum: a solid base



For the arm: something long and sturdy

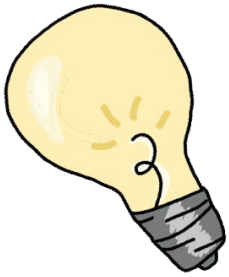


Step 1: Center the lever arm over the fulcrum.



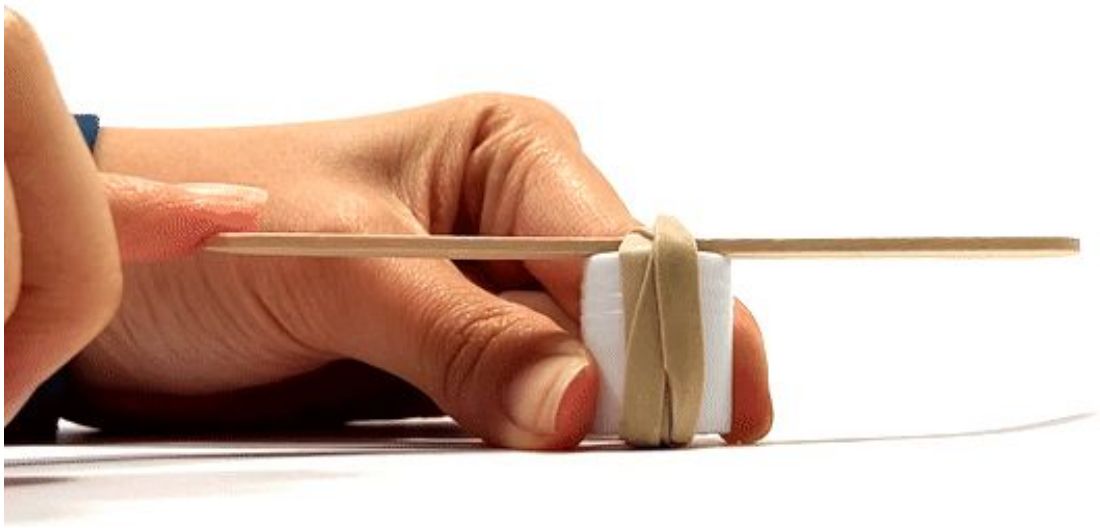
Step 2: Rubberband the level arm onto the fulcrum.

Push on one side of the level arm to lift the other side!



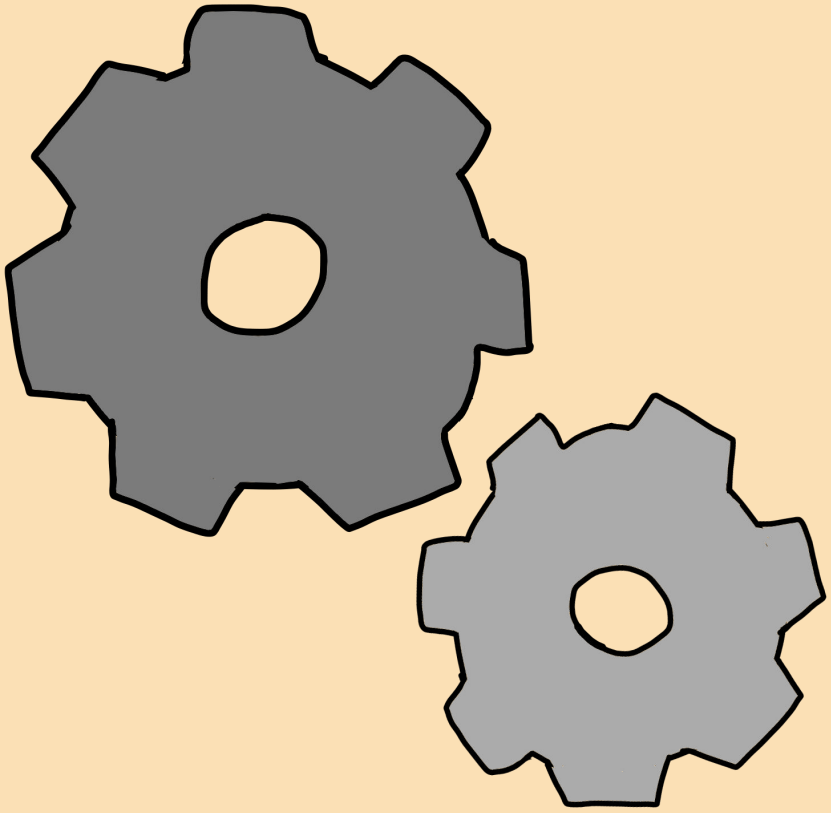
You will probably need to secure the fulcrum to a base in your big project so the lever doesn't move around.

Watch the lever in action!




NEWS!

Movement



Get those pieces moving.

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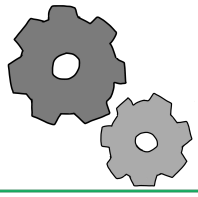
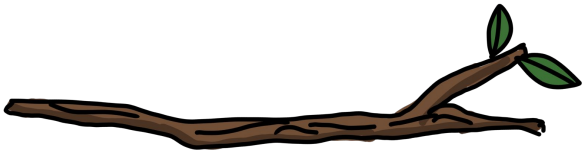
Wheels and axles



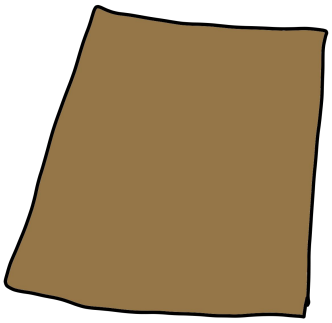
For the wheels: x2 something circular and smooth

For the axle: something long

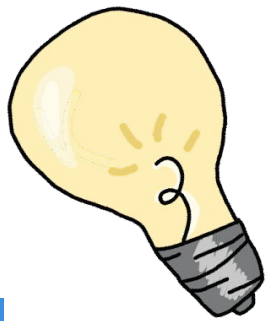


Connecting wheel and axle:

← For thin axles: straw



← For any axles: cereal box cardboard



The axle must rotate inside the straw or a loosely looped piece of cardboard.

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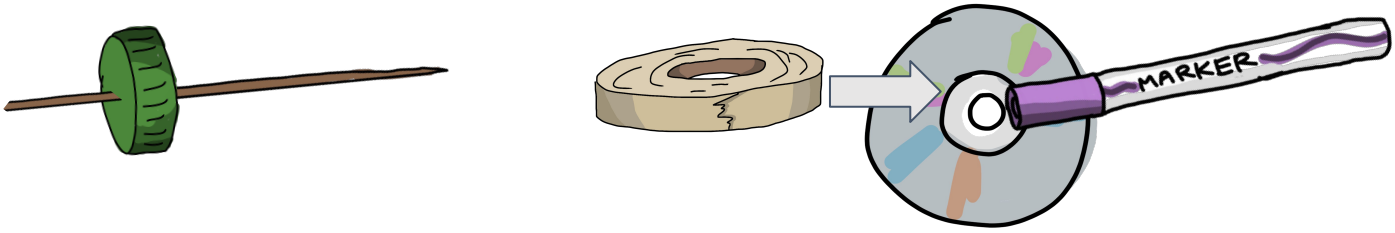
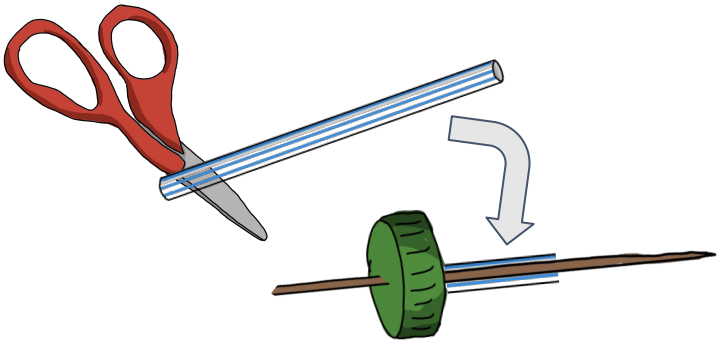
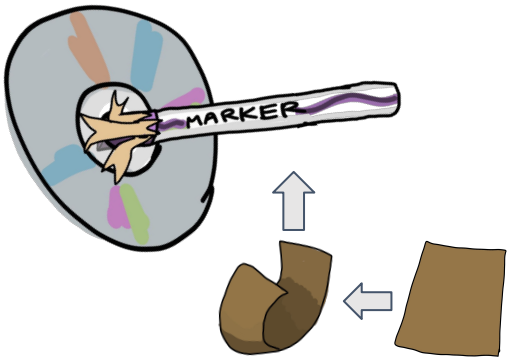
Step 1: Attach one wheel to axle, using tape to secure if necessary.



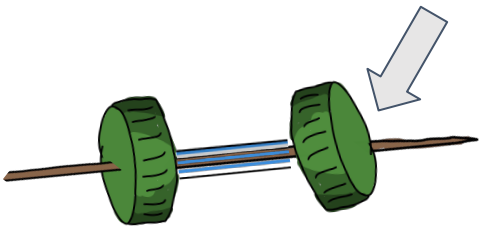
Step 2 Option A: For thin axles, cut a piece of straw and put on axle.

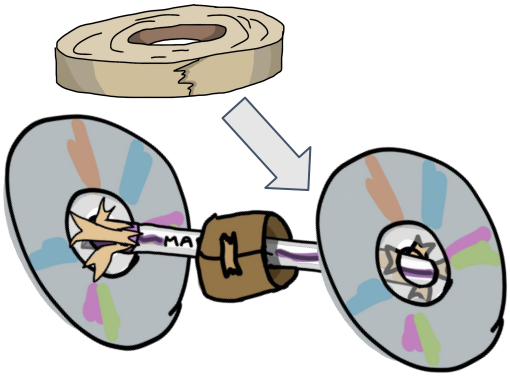


Step 2 Option B: For thicker axles, loosely wrap a piece of cereal box paper around axle, secure the loop with tape.

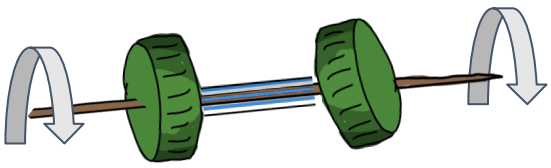


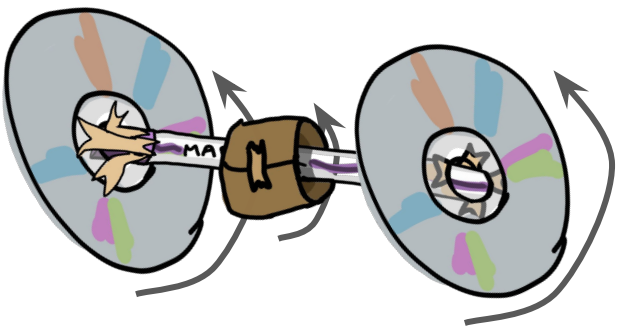
Step 3: Attach the second wheel.



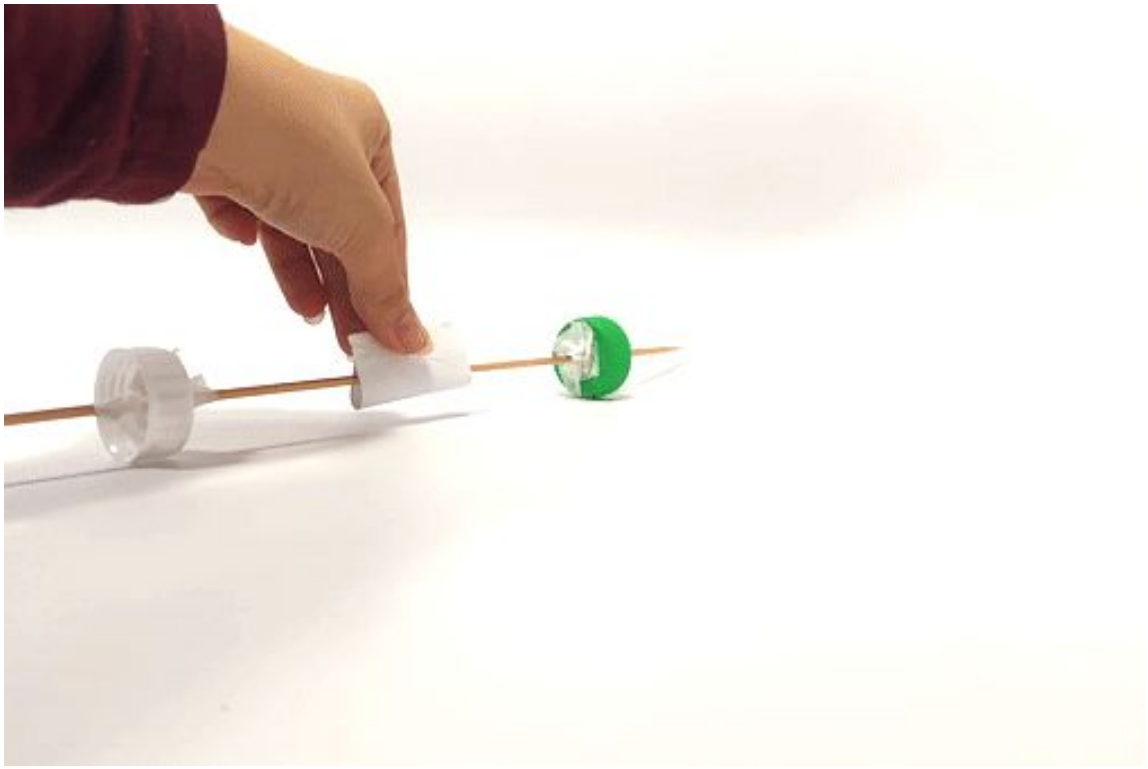


Step 4: Hold onto the paper loop or straw, and roll your wheel! The wheels and axle should rotate inside of the loop.

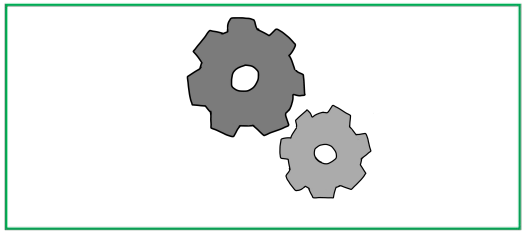




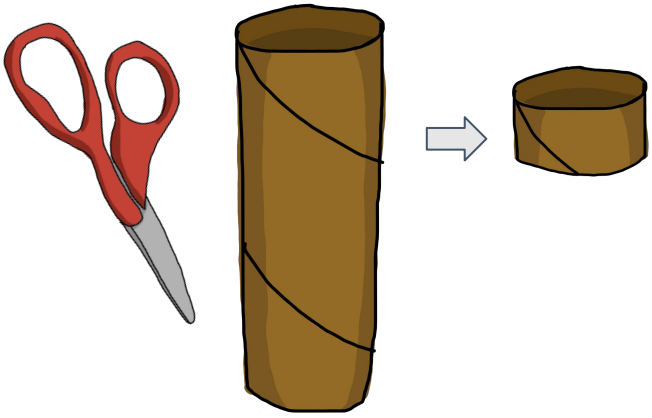
Watch the wheels roll!



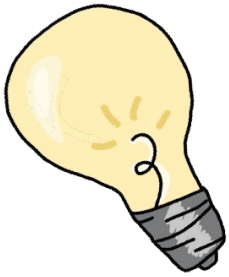
Paper tube wheels



Step 1: Cut a piece of paper tube.

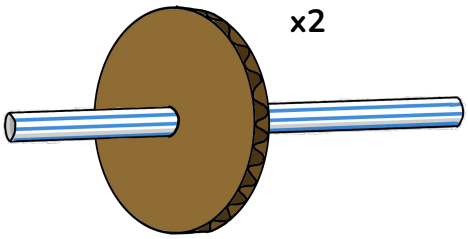


Step 2: Trace the paper tube twice on cardboard, cut out. Make sure they fit over the paper tube like caps.

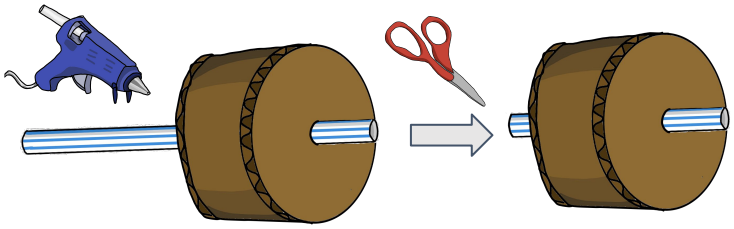


Be sure to trace the outside so the tube so caps are slightly larger than the tube.

Step 3: Carefully use the wooden dowel to poke a hole through the center of both caps. Use a pencil to widen the hole so that the straw fits tightly.

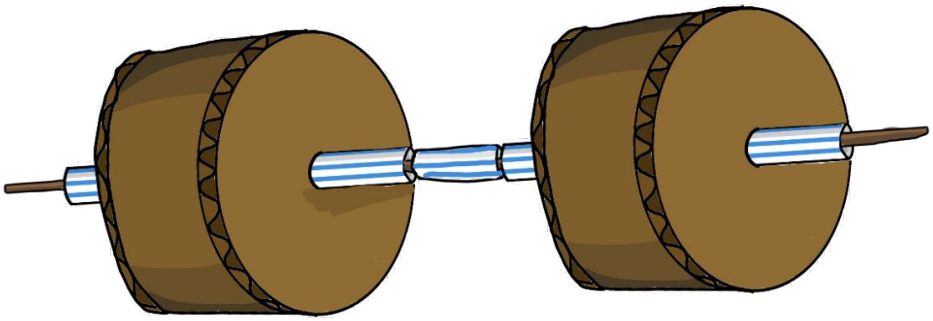


Step 4: Glue the caps to the tubes. Insert and cut the straw so a little sticks out of both sides.



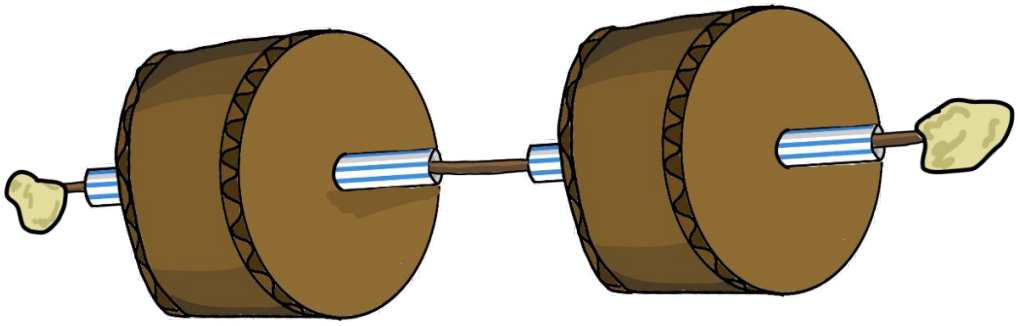
Repeat steps 1 - 4 to make another wheel.

Step 5: Place both wheels onto a skewer. Cut a small piece of straw and place in between wheels on the skewer. The wheels should rotate around the skewer.



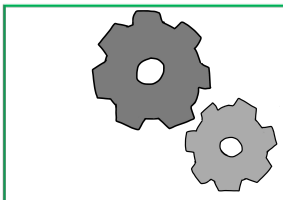
Another option:

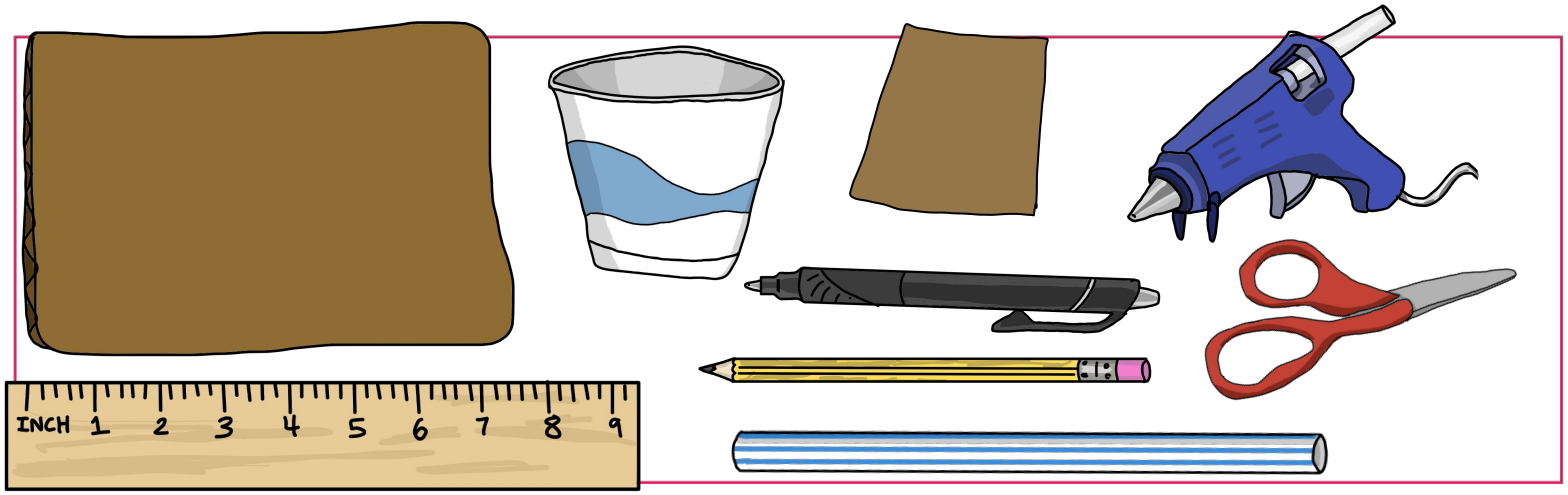
b) To keep wheels from sliding off, place a piece of tape or clay at the ends

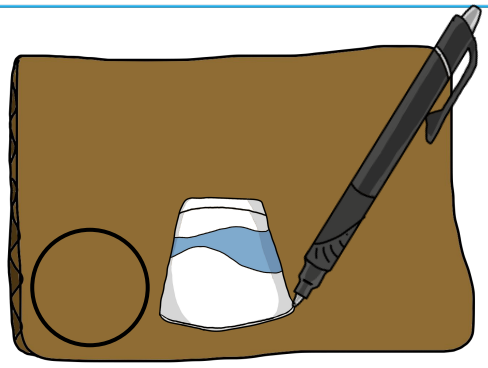


Watch the wheels roll!

Cardboard wheels

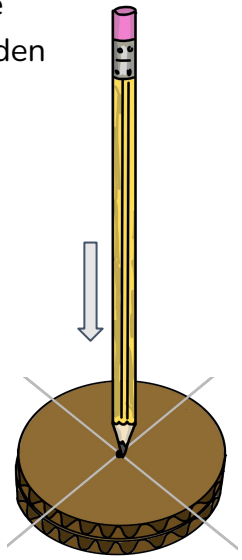




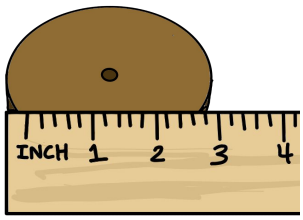


Step 1: Trace a circular object and cut two circles out of cardboard.

Step 2: Carefully use a pencil to poke through the center of both circles. Widen the holes until the straw fits in tightly.



Step 3: Approximate the circumference by measuring the diameter and multiplying by 3.5.



Example
Diameter: 3 in
Circumference: 3 x 3.5 = 10.5 in

You can replace the straw with a skewer, and replace the cardstock loop with a straw!

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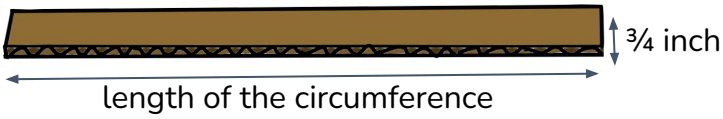
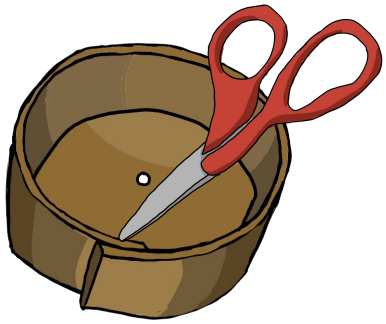
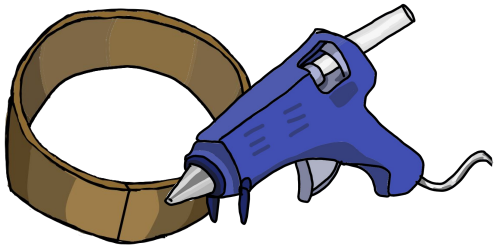
Step 4: Cut a strip of cardboard as follows:

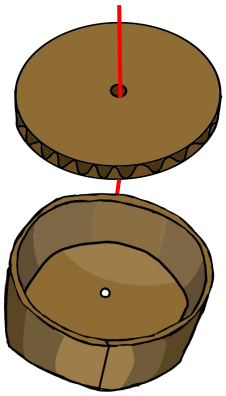


Step 5: Wrap the strip around a circle, cut the strip where it overlaps.

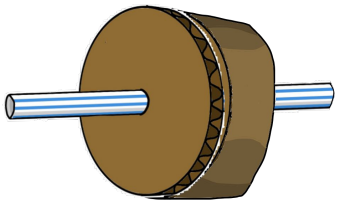


Step 6: Glue so the ridges at the ends meet.

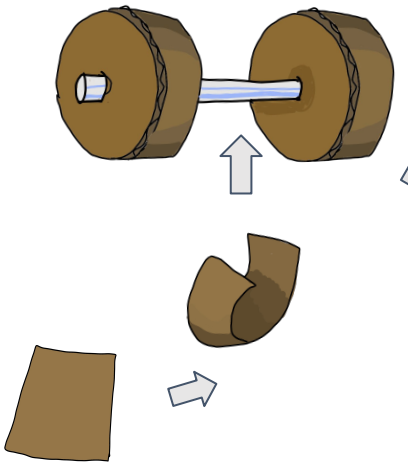




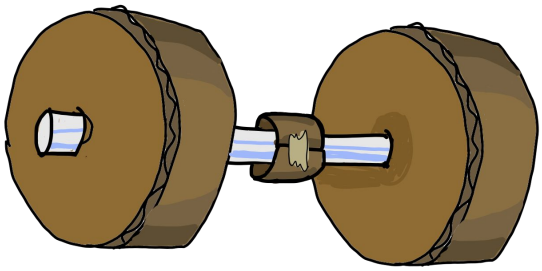
Step 7: Glue one circle to the bottom of the ring, and glue the other circle to the top. Insert a straw.



Repeat Steps 1-7 to make another wheel.



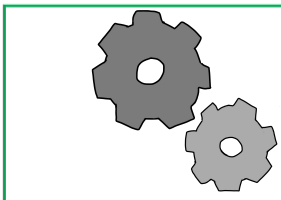
Step 8: Place both wheels on the straw. Cut a small piece of cardstock and wrap loosely around the straw and tape.

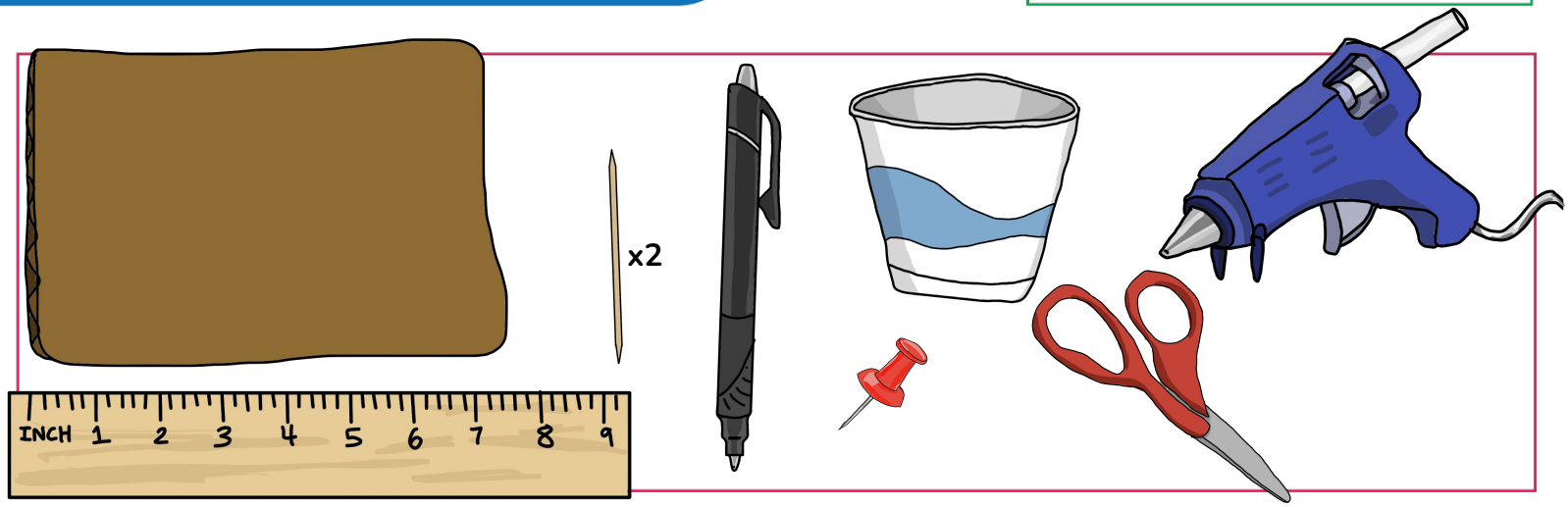


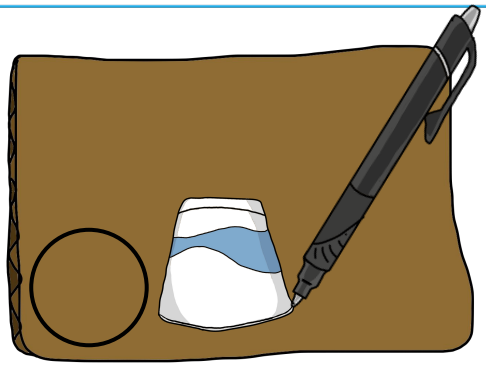
Hold onto the paper tube and roll the wheels!

Watch how it rolls !

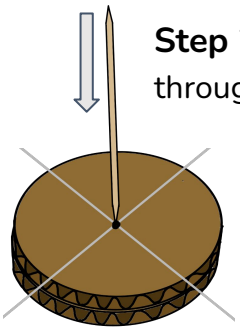
Cardboard gears





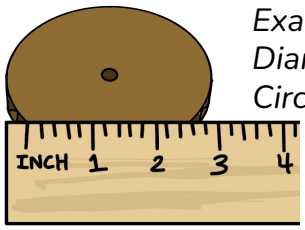


Step 1: Trace a circular object and cut two circles out of cardboard.



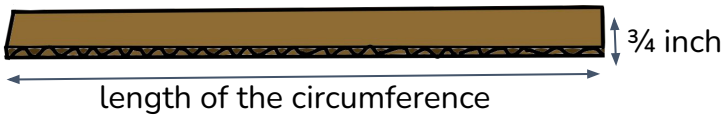
Step 2: Use toothpick to poke through the center of both circles.

Step 3: Approximate the circumference by measuring the diameter and multiplying by 3.5.



Example:
Diameter: 3 in
Circumference: 3 x 3.5 = 10.5 in

Step 4: With the corrugation on the long side, cut a strip of cardboard as follows:



Don't waste cardboard! Place tracings as close together and to the edge as possible.

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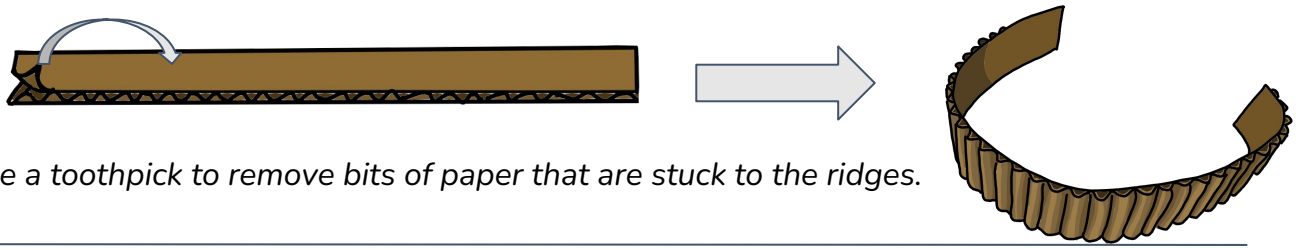
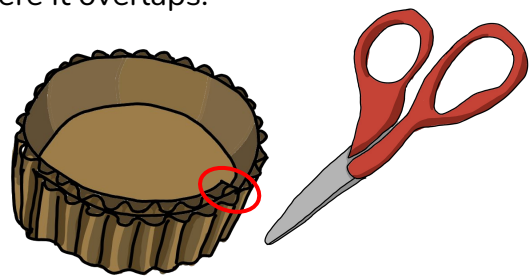
Adapted from Education.com

Step 5: Peel back the paper from one side of the strip, leaving the ridges exposed.

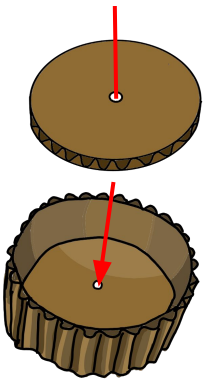


Use a toothpick to remove bits of paper that are stuck to the ridges.

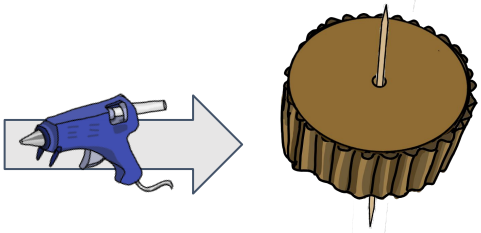
Step 6: Wrap the strip around a circle, cut the strip where it overlaps.



Step 7: Glue so the ridges at the ends meet.

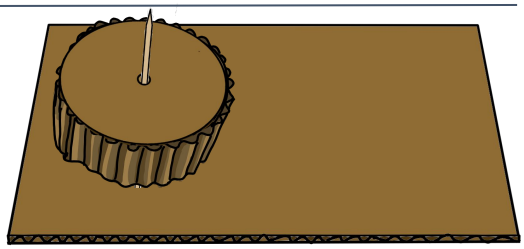


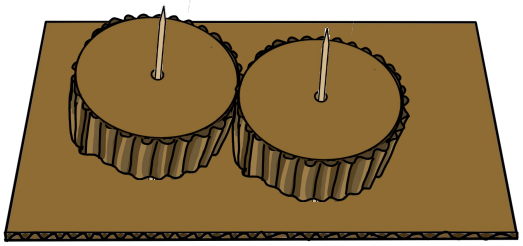
Step 8: Glue one circle to the bottom of the ring, and glue the other circle to the top. Insert a toothpick.



Repeat Steps 1-8 to make another gear.

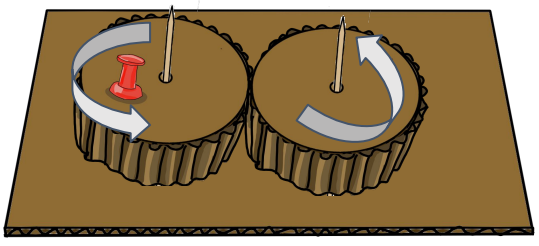
Step 9: Get another piece of cardboard. Poke one gear onto the left side.





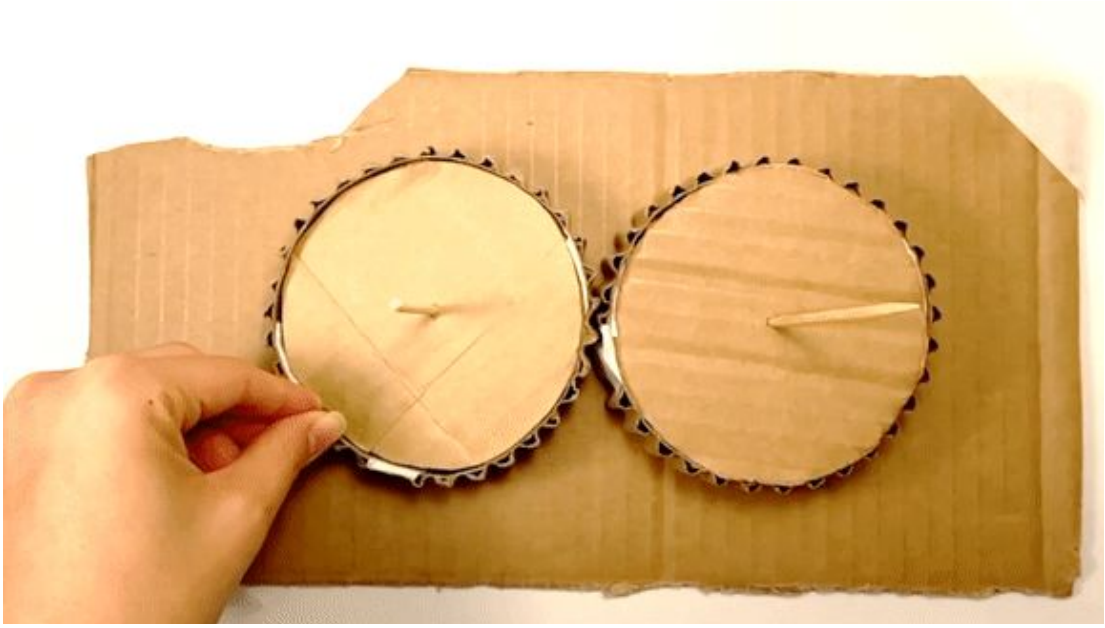
Step 10: Line up the second gear so that the grooves fit together. Poke in second gear.

Step 11: Push a push pin into one gear, this is your handle to turn the gears!

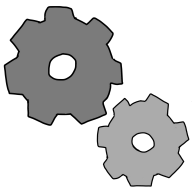


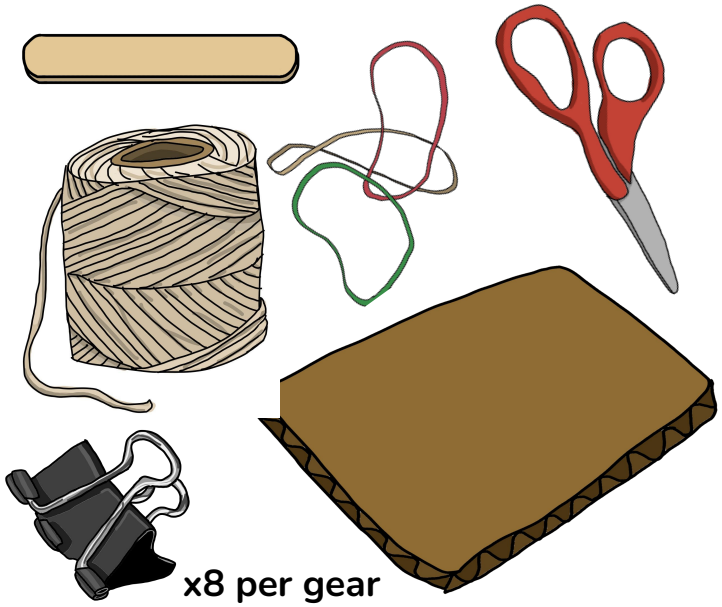
How to peel the cardboard:

Watch the gears turn!



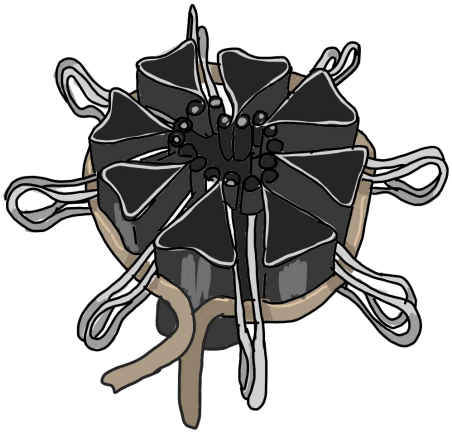
Binder clip gears

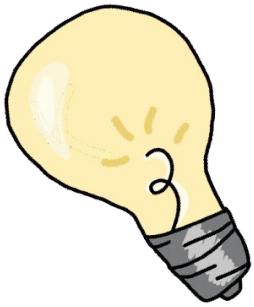




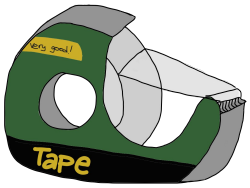
Step 1: With the arms bent up, string binder clips onto a piece of string.

Step 2: Point the binder clips inwards and form a circle.





If the clips are shifting a lot, use bits of tape to tape the handles together.



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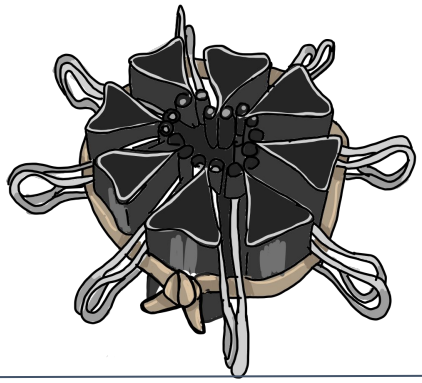
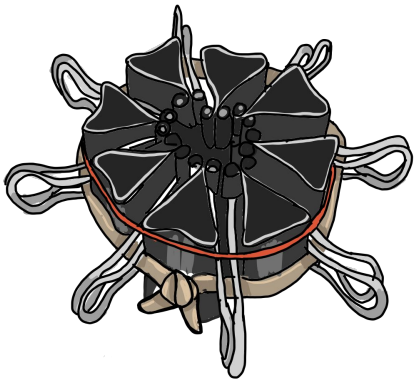
Step 3: Pull the string tight and tie. Trim excess string.

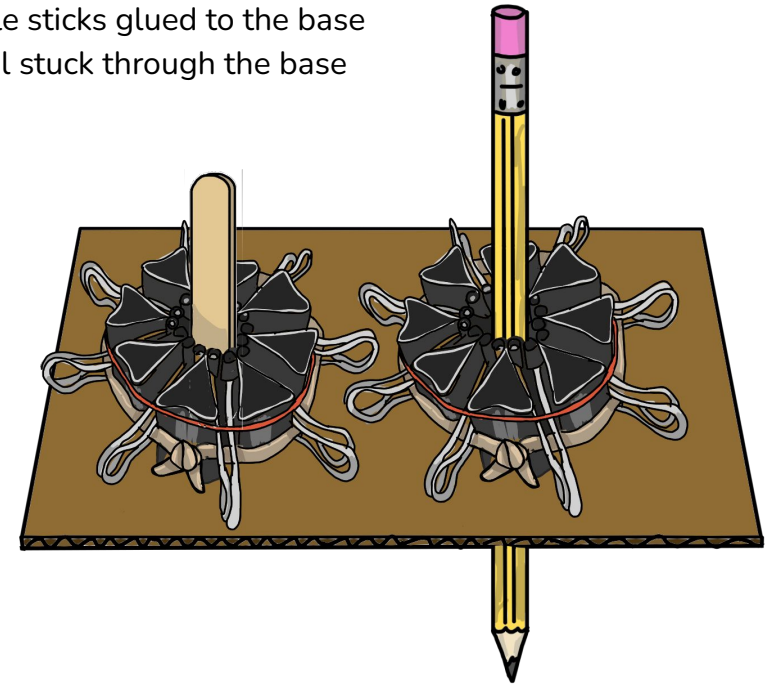




Step 4: Loop one rubber band on the top and bottom of the gear.

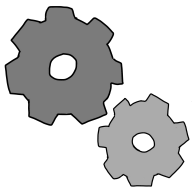
Step 5: Connect to a base. Here are a couple ideas:

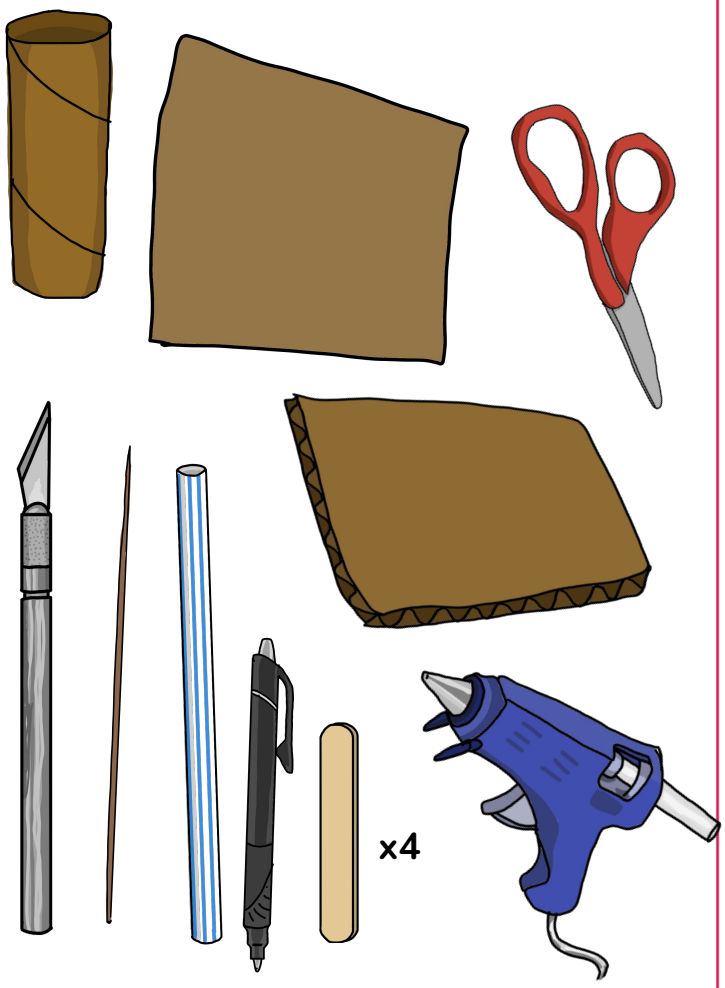
- popsicle sticks glued to the base
- a pencil stuck through the base



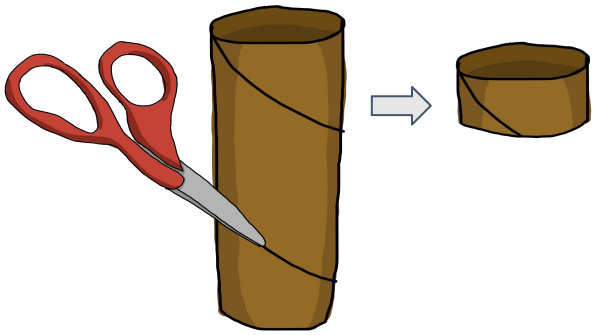
Watch the gears turn!

Tube Propellers

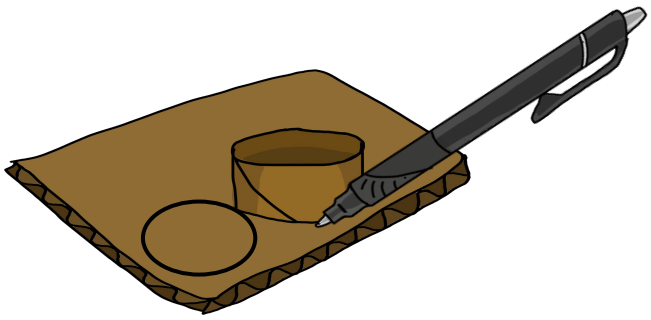


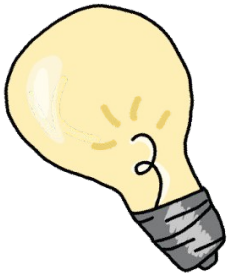


Step 1: Cut a 1 inch long piece of paper tube.



Step 2: Trace the paper tube twice on cardboard, cut out. Make sure they fit over the paper tube like caps.

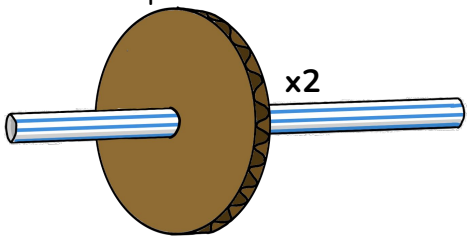




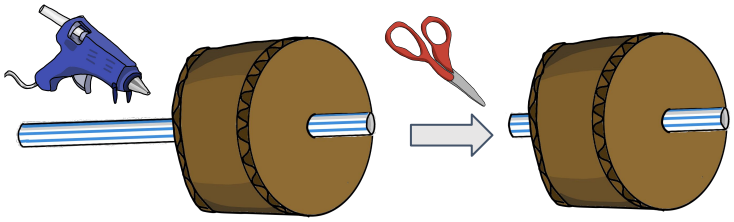
Be sure to trace the outside of the tube so the caps are larger than the tubes.

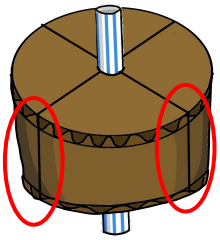
Have an adult help with the X-ACTO knife!

Step 3: Poke a hole through the center of both caps so that the straw fits tightly.



Step 4: Glue the caps. Insert and cut the straw so a little sticks out of both sides.

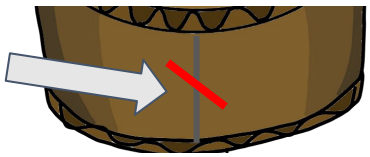


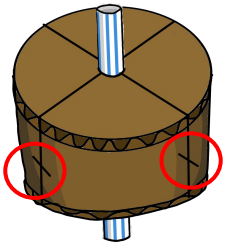


Step 5: Draw an X through the center of the cap and extend the lines down onto the side of the tube.

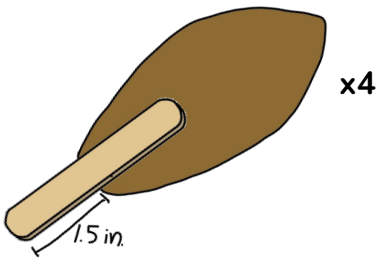
There are now 4 evenly spaced lines along the tube.

Step 6: Ask an adult to use an X-ACTO knife to cut a slash at a 45° angle through the middle of each line. The cut should be the width of the popsicle stick

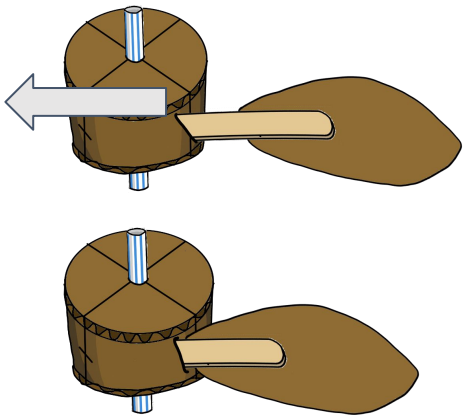


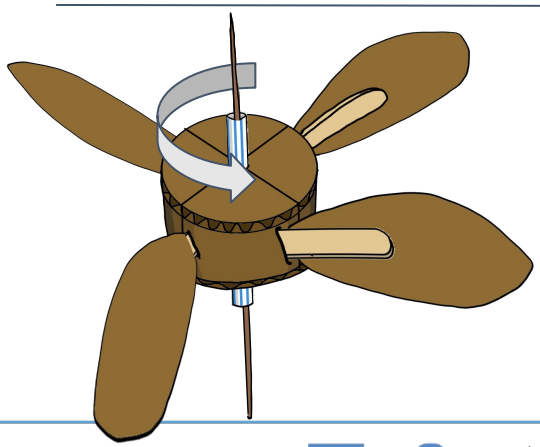


Step 7: Cut 4 blades out of cereal box cardboard. Glue the blades onto popsicle sticks, leaving at least 1.5 inches of stick exposed.



Step 8: Slide the popsicle stick blades into the slits in the side of the tube.

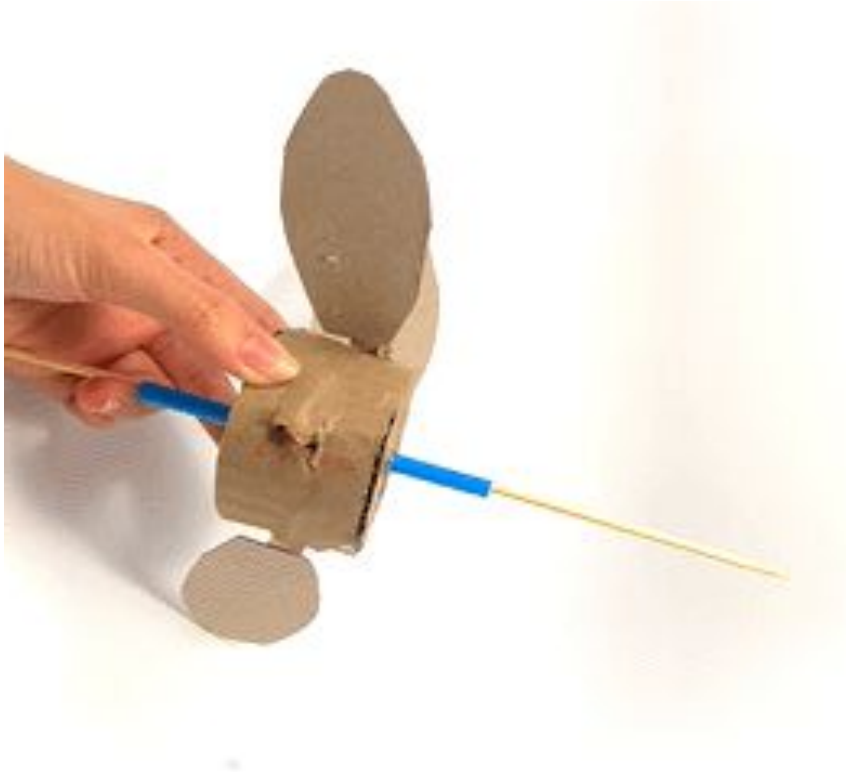




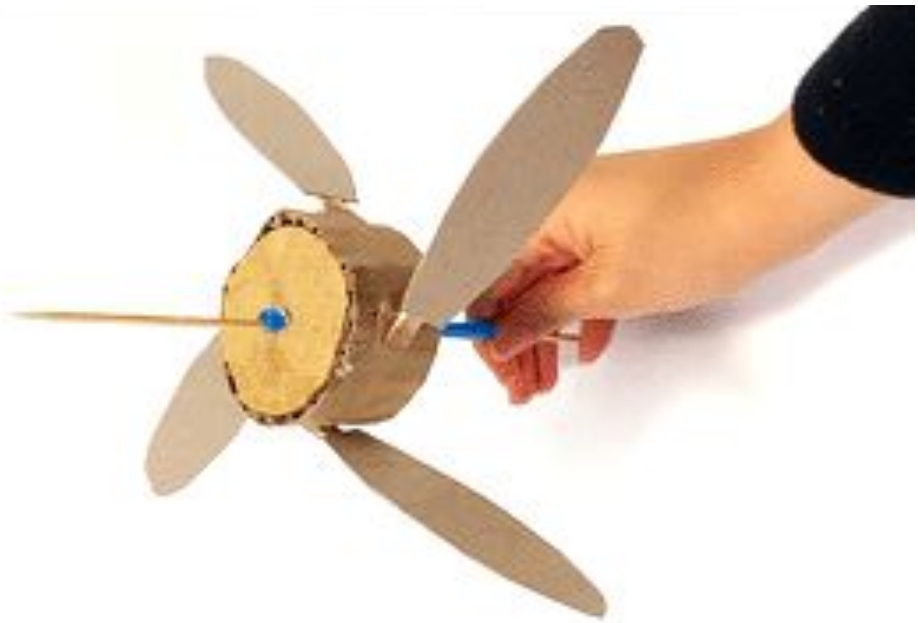
Step 9: Insert a wooden dowel through the straw.

Hold the propellor by the dowel. The propellor should spin around the dowel.

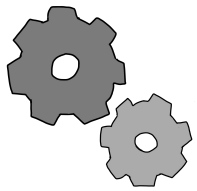
How to insert the blades:

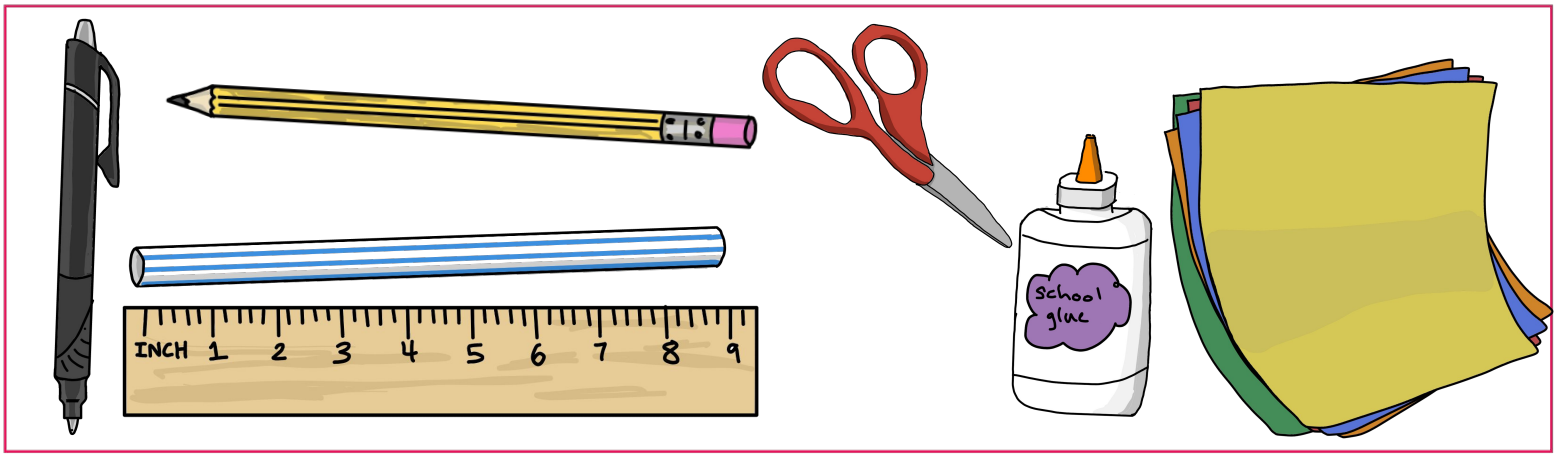


Watch the propeller spin!

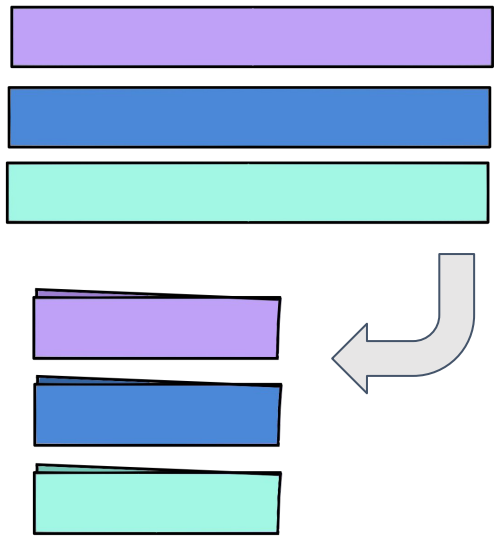


Paper propellers

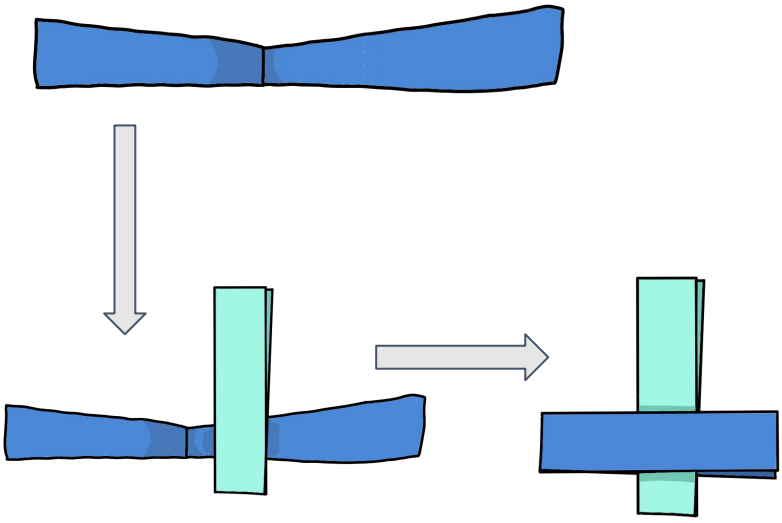




Step 1: Cut out 3 strips of paper that are 1 inch by 6-8 inches. Fold in half.



Step 2: Open a strip. Place a folded strip with the open end pointing up onto the open strip and close.



If the axle is too thin, the spinning will be wobbly.

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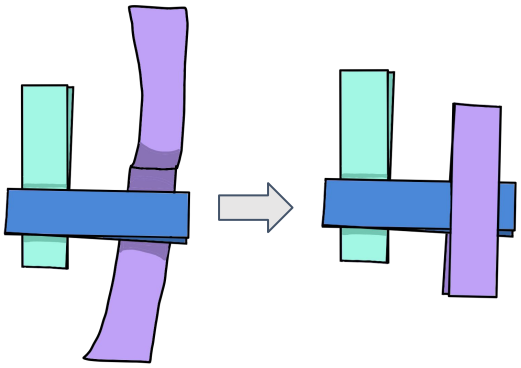
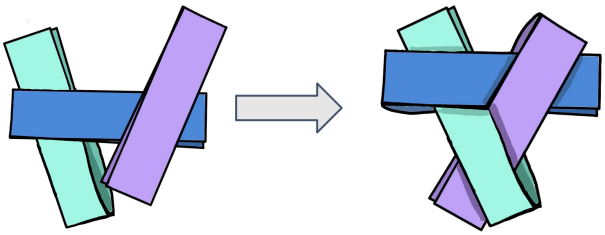
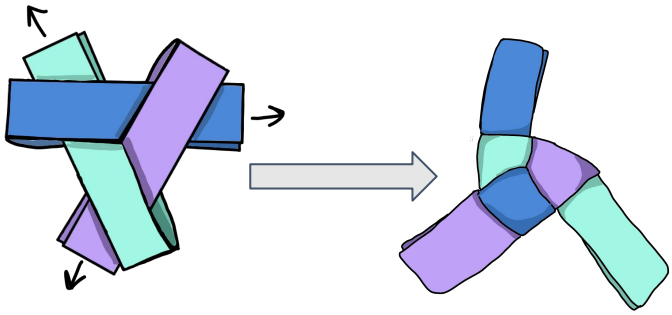
Step 3: Open the unused strip, slide it under the horizontal strip and close.



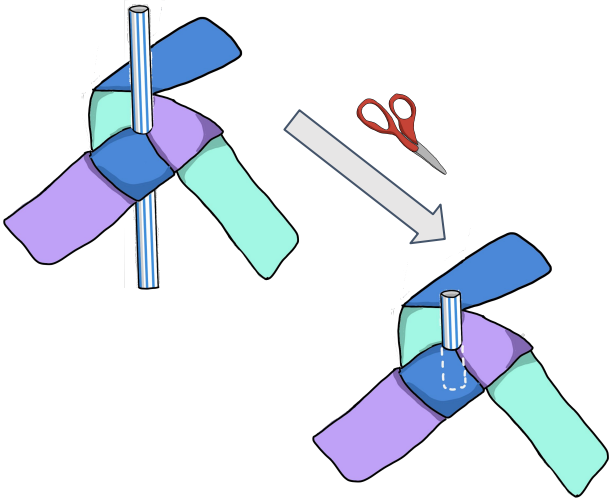
Step 4: Tuck the strip on the right into the loop of the strip on the left.



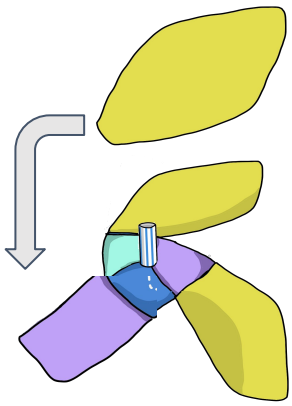
Step 5: Shift the loop ends towards the center by gently pulling the open ends, making a domed triangle shape. Glue into this shape.



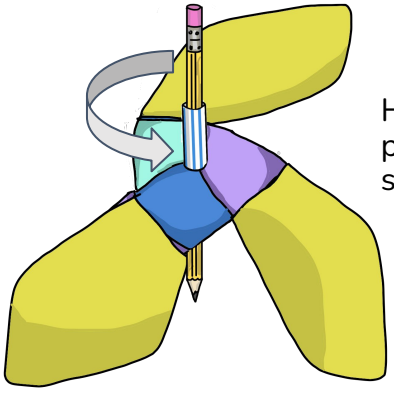
Step 6: Use a pencil to make a hole at the tip of the triangle for the straw. Cut to be around 1 inch long. Secure with glue.



Step 7: Design 3 blades and cut out of paper. Glue onto the "arms" of the triangle.



Step 8: Insert a wooden dowel or pencil through the straw.

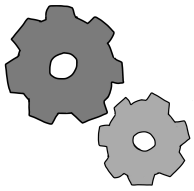


Hold the propeller by the pencil. The blades should spin around the pencil.

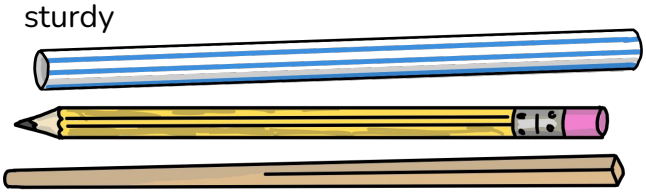
How to pull the paper together:

Watch the propeller spin!

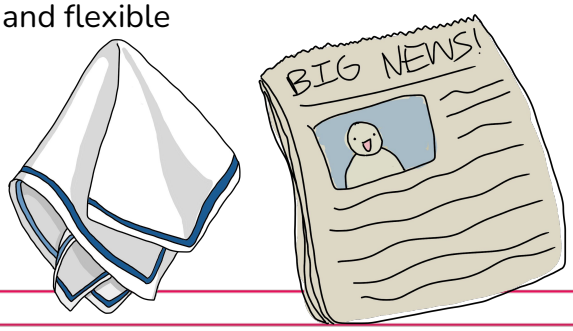
Conveyor belt

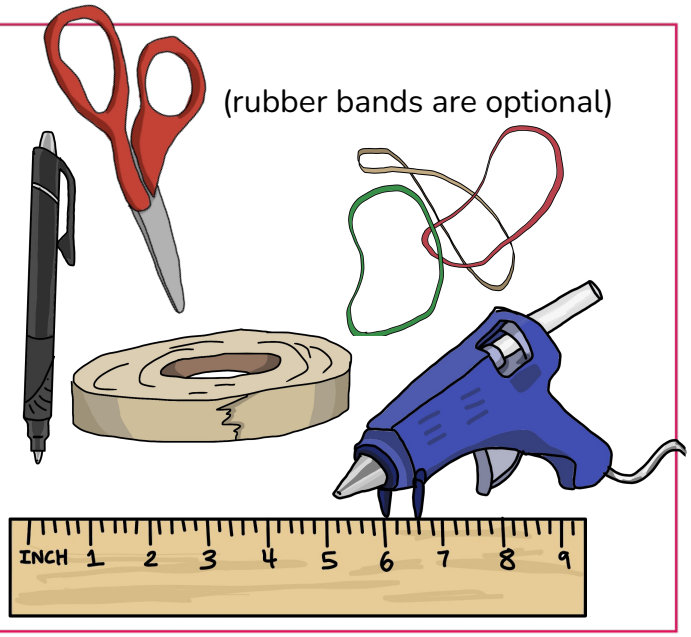


For the handles: 2 of something long and sturdy



For the conveyor belt: something long, flat and flexible



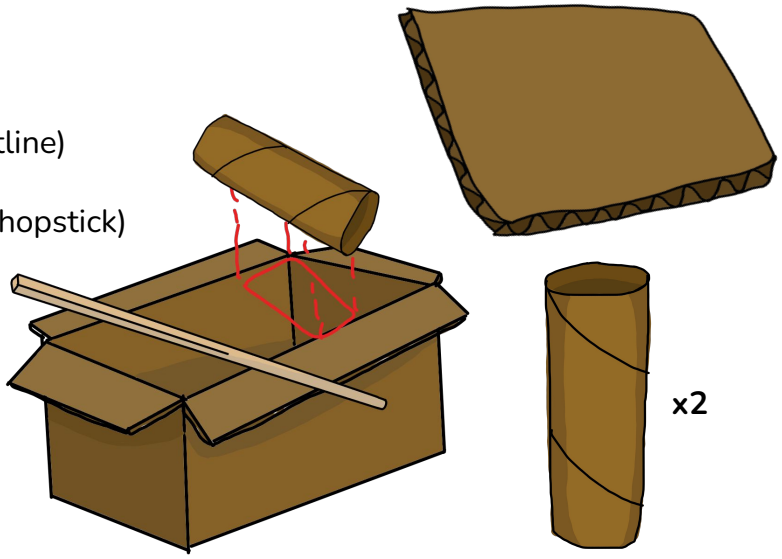


(rubber bands are optional)

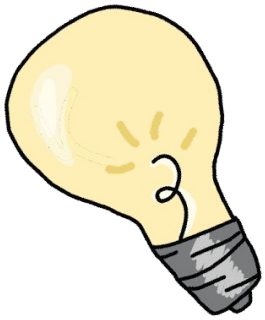
Cardboard box with dimensions so that:

1) 2 paper tubes fit side by side (red outline)

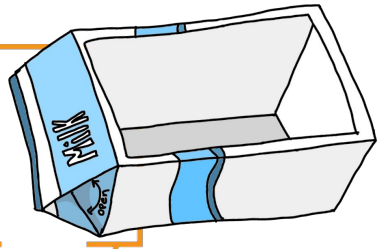
2) The handle can rest across the top (chopstick)



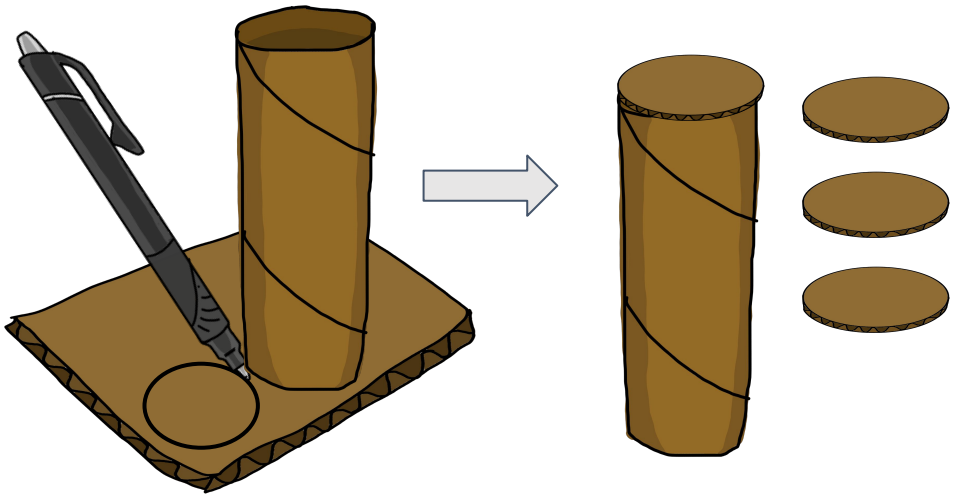
x2



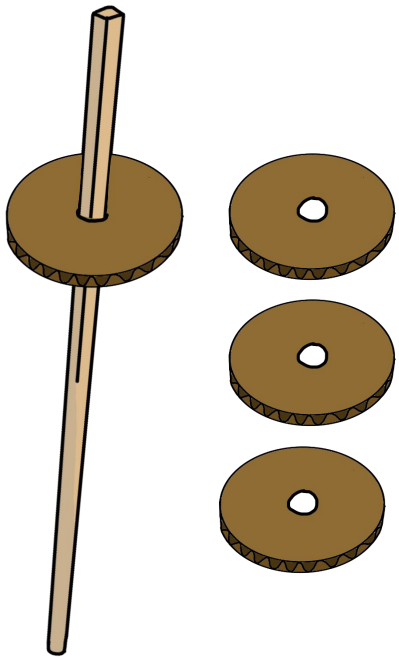
You can use a milk carton with a side cut out instead of a box!



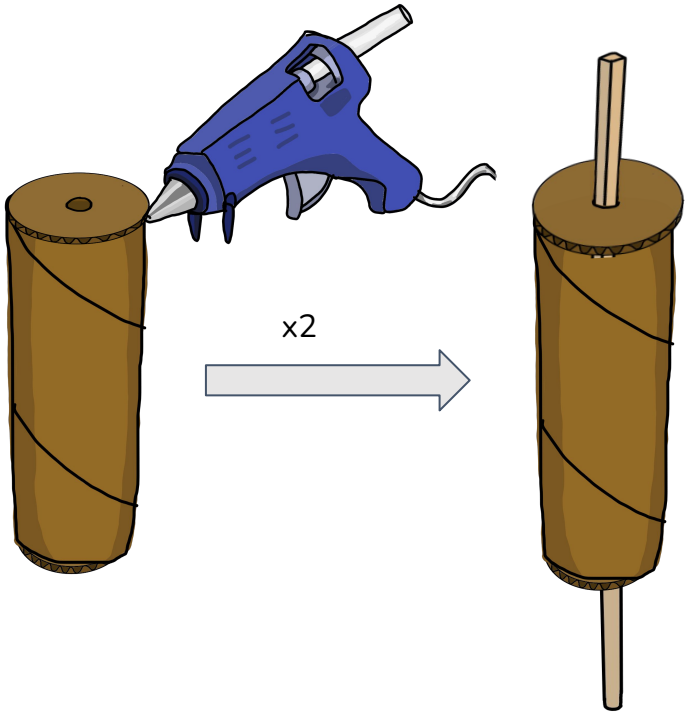
Step 1: Trace the end of a paper tube 4 times onto cardboard and cut out. Make sure these fit nicely over the ends of the tubes like caps.



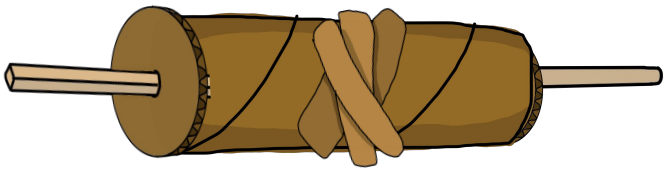
Step 2: Poke a hole through the center of each cap so your handle fits tightly.



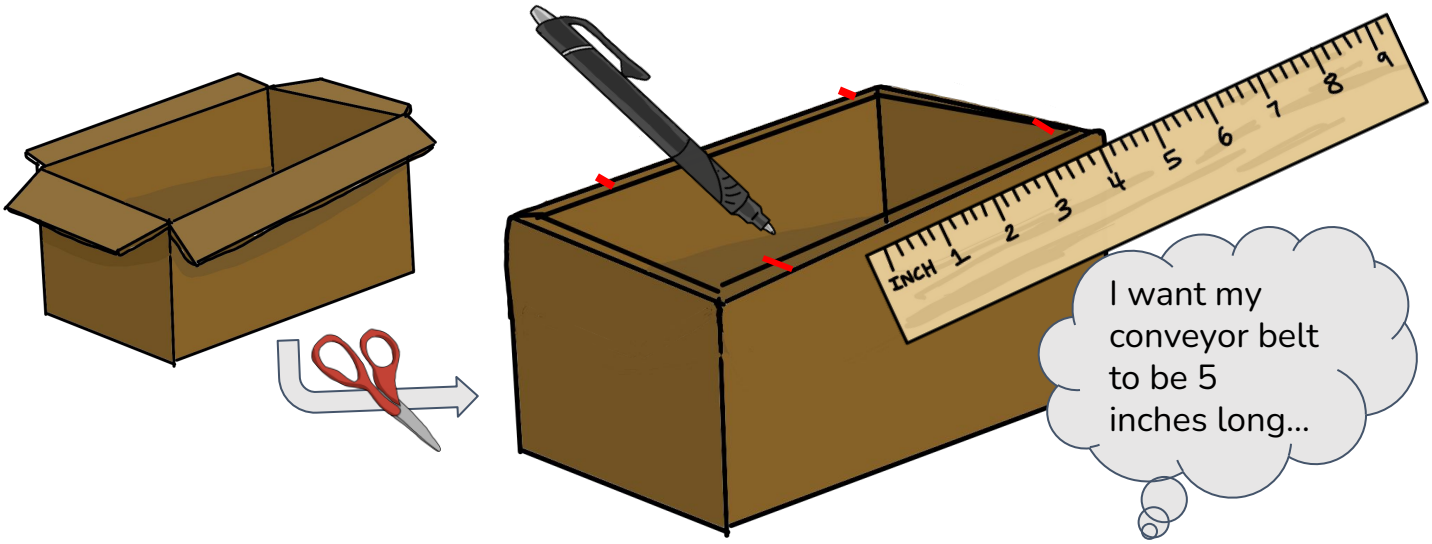
Step 3: Hot glue caps onto each end of the tubes. Insert handles.



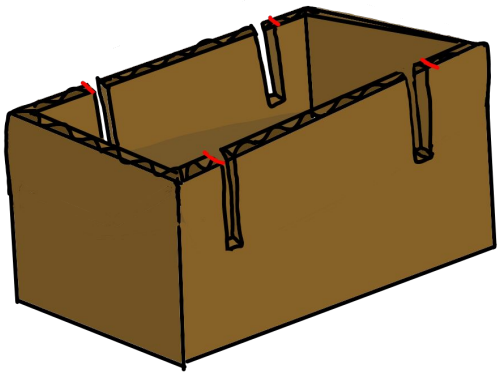
Optional: For extra grip on the conveyor belt, tightly wrap a rubberband around each tube.



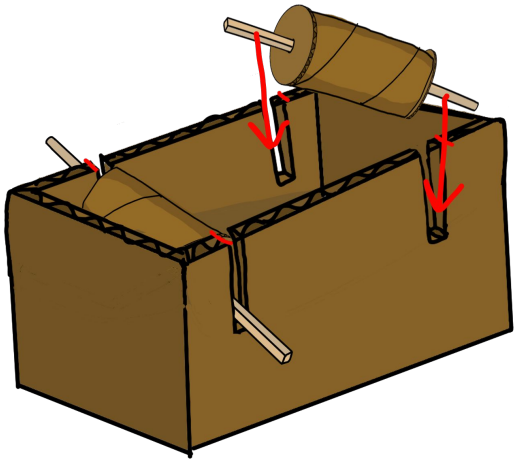
Step 4: Cut the flaps off the box. Draw two lines on each side of the box marking the conveyor belt's length (red marks).



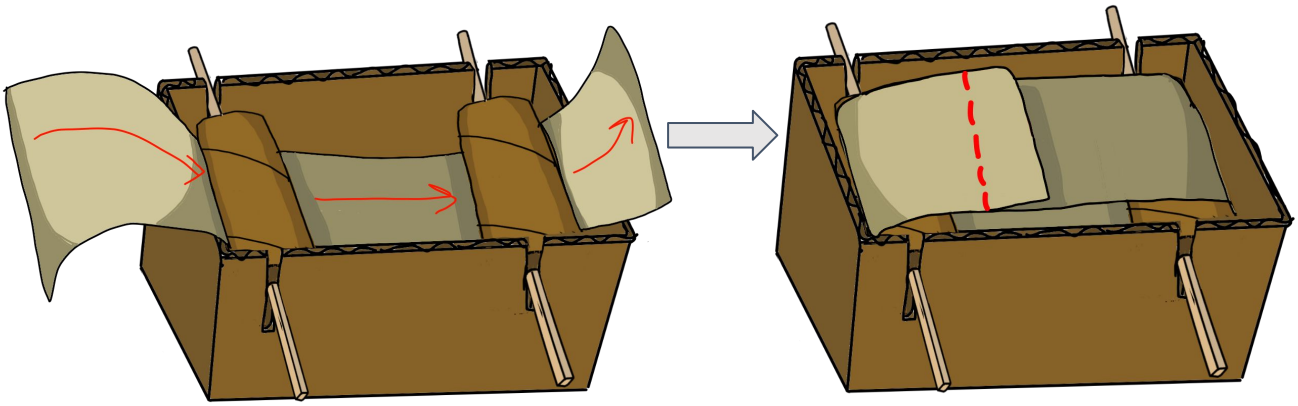
Step 5: Use scissors to cut slits down the lines at least 2 inches down.



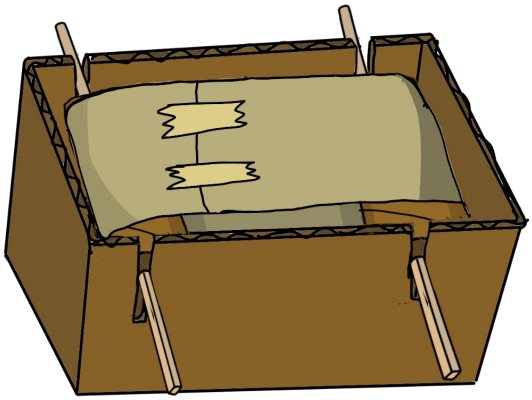
Step 6: Slide the handles into the slits. Make sure that you can spin the tube by turning the handle and widen slits if necessary.



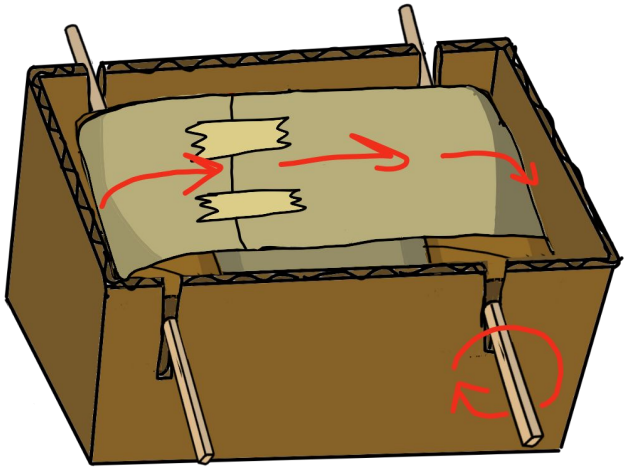
Step 7: Cut your conveyor belt material to fit in the box. Loop it under the tubes tightly, then mark where the material overlaps.



Step 8: Cut the material at the overlap mark, then tape the loop shut.



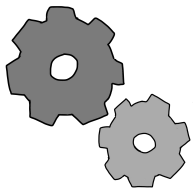
Step 9: Move the conveyor belt by turning a handle. If the belt does not move, try tightening the loop or adding rubber bands around the tubes.

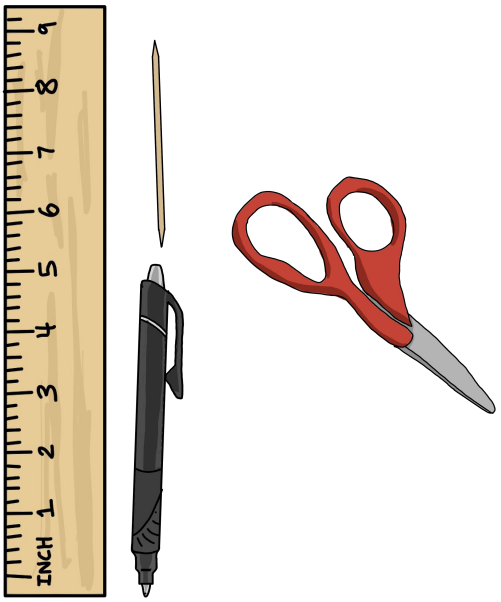


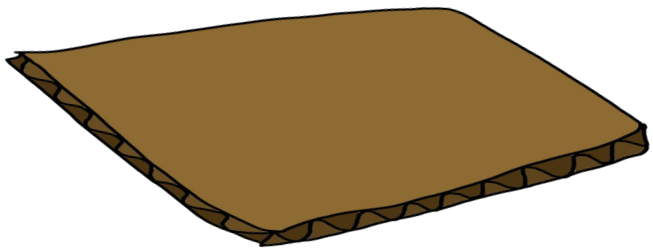
How to loop the belt around the tubes:

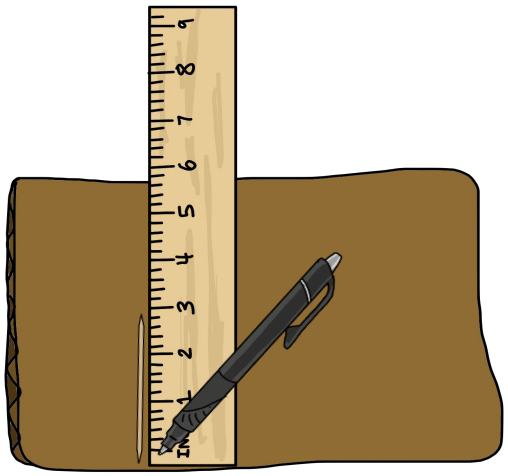
Watch the conveyor belt move!

"Door" Hinges

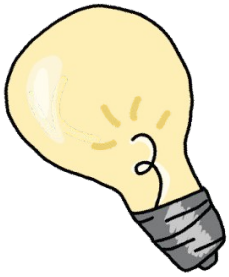






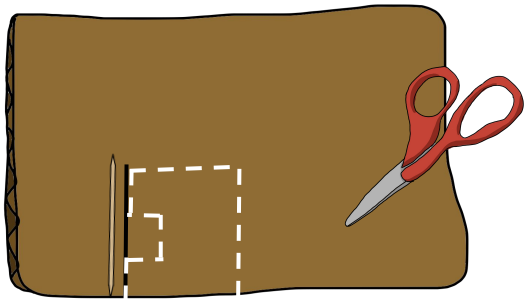


Step 1: Draw a line from the bottom of the cardboard to a little shorter than the toothpick.

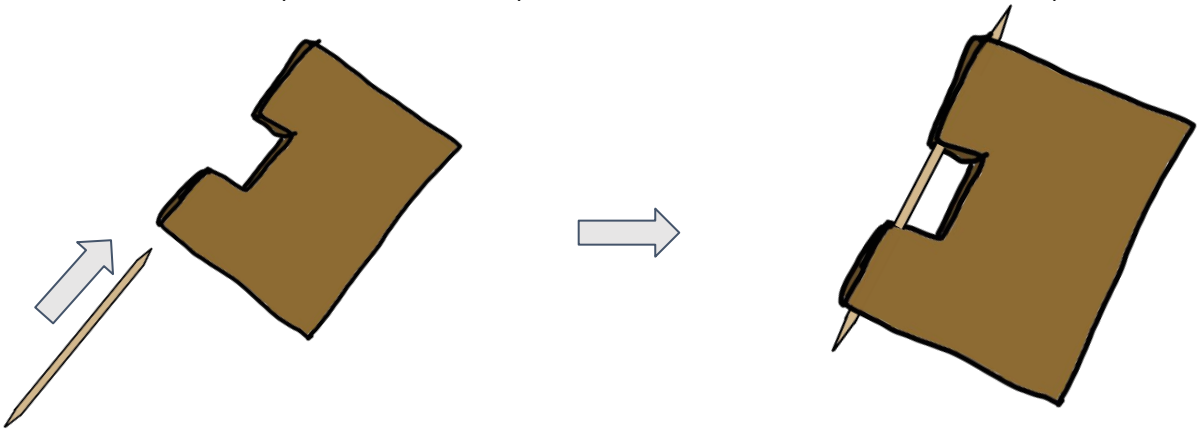


For a larger hinge, a skewer can be used instead of a toothpick.

Step 2: Draw a shape like the one shown in white. Cut the shape out.

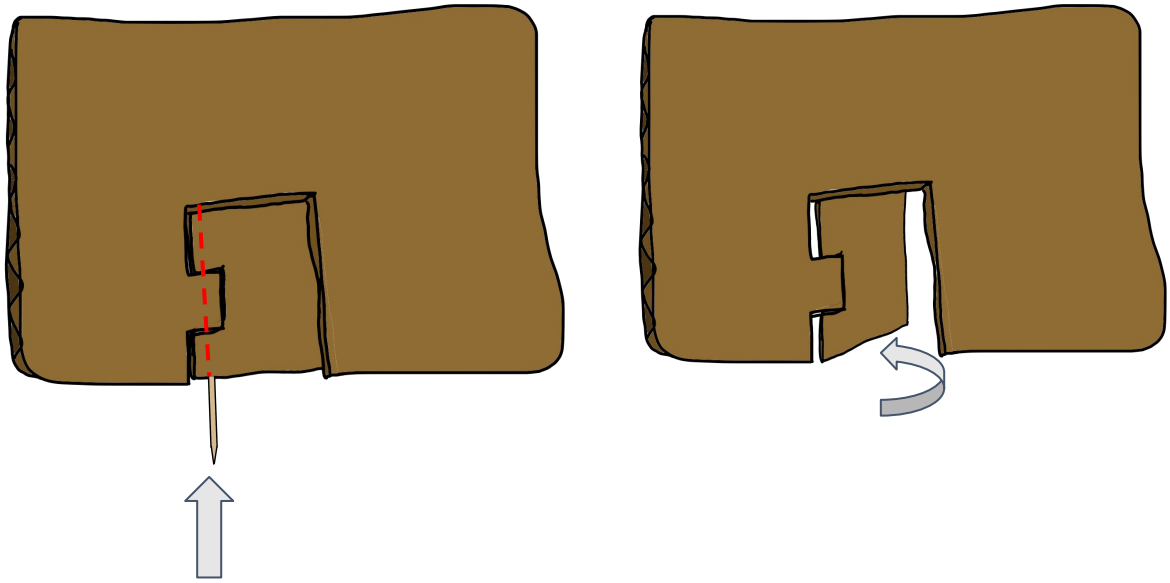


Step 3: Insert the toothpick into the cut piece of cardboard. Remove the toothpick.



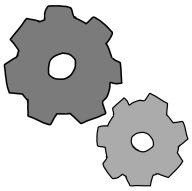
Step 4: Fit the cut piece back into place. Insert the toothpick up through the vertical tabs, keeping the "door" in place.

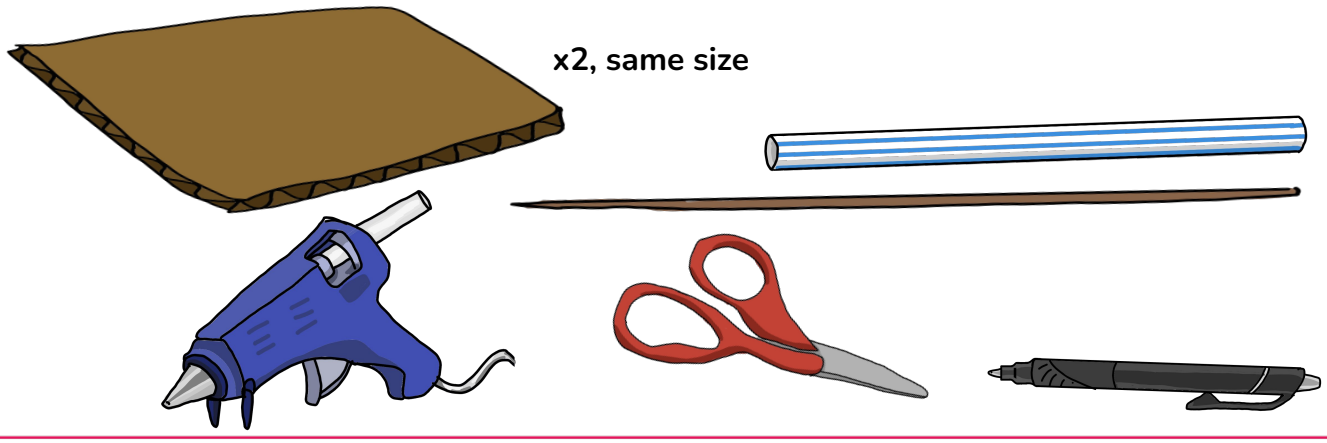
The toothpick's path is shown in red. The hinge should now rotate!



Watch the hinge rotate!

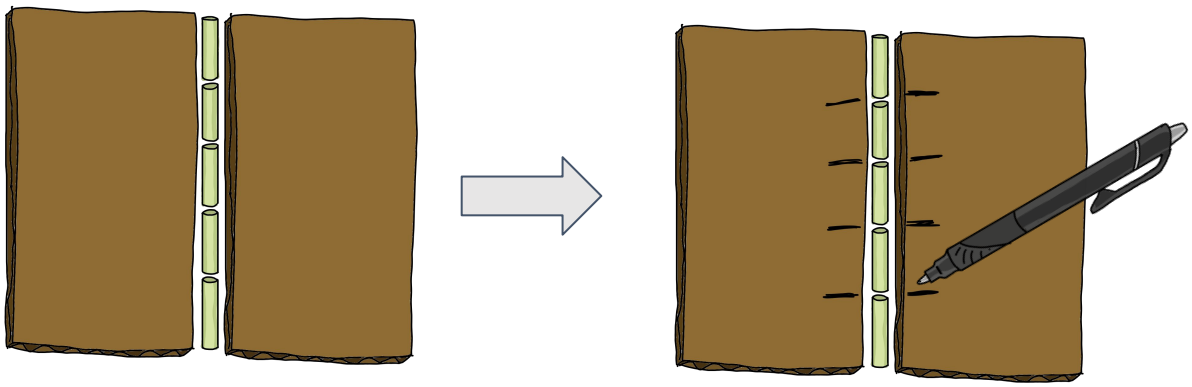
Straw Hinges





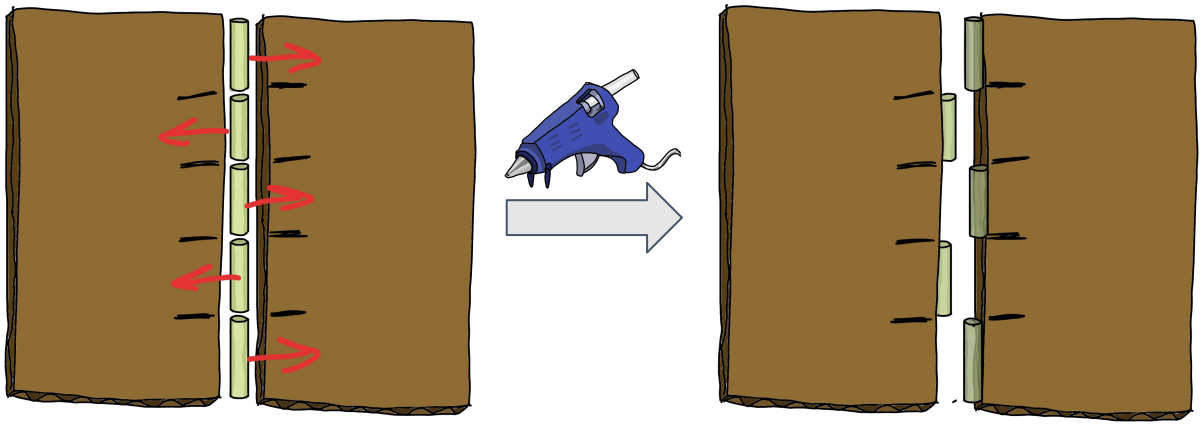
Step 1: Cut the straw to the height of your cardboard pieces, then cut into multiple smaller pieces.

Step 2: Line up the pieces in between the cardboard. Mark on both pieces where the straw bits start and end.

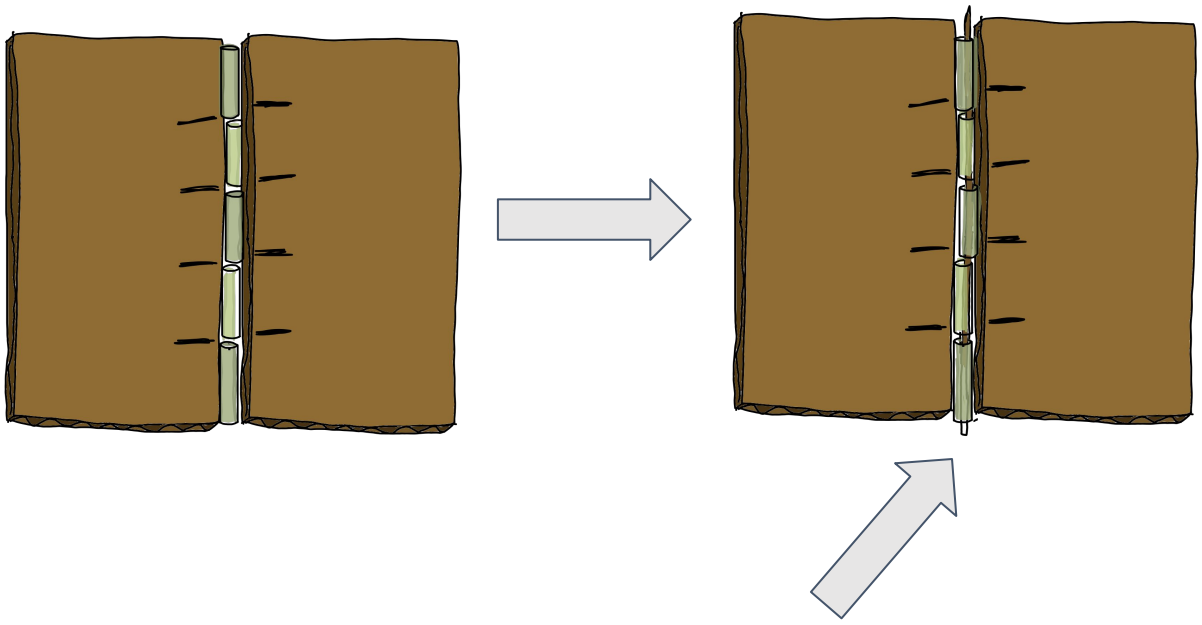


You can use a toothpick or pencil instead of a dowel if it fits in the straw.

Step 3: Alternate straw bits between the two cardboard pieces. Glue to the cardboard.



Step 4: Put the two pieces together so the straws are in line. Insert a wooden dowel.

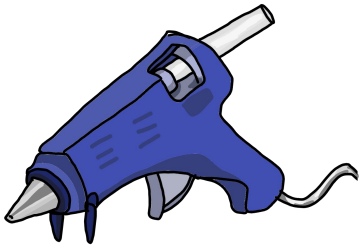


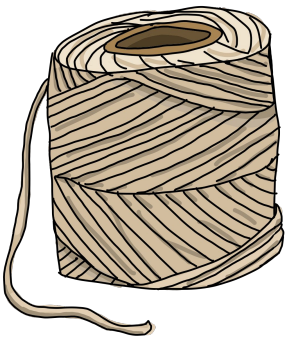
If the hinge falls out easily, try capping the ends with clay, hot glue, or tape

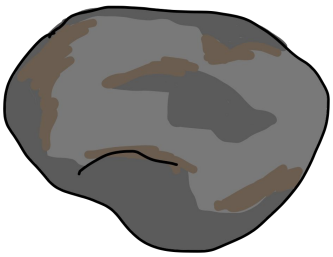
Watch the hinge rotate!

Pendulum

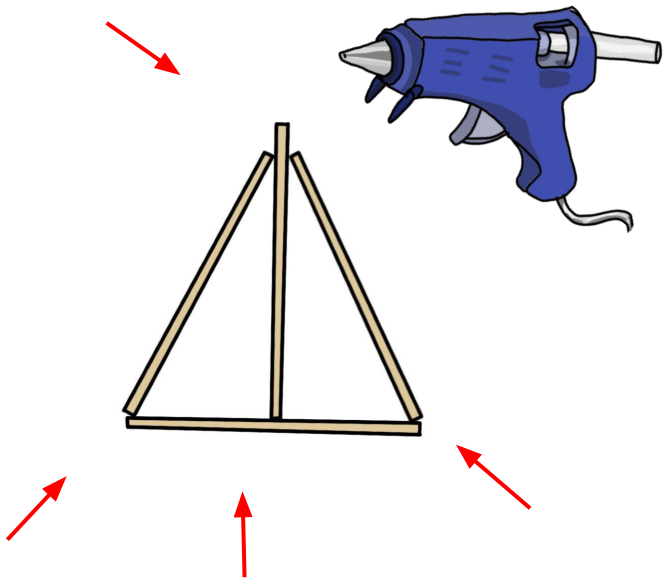
x9 or more



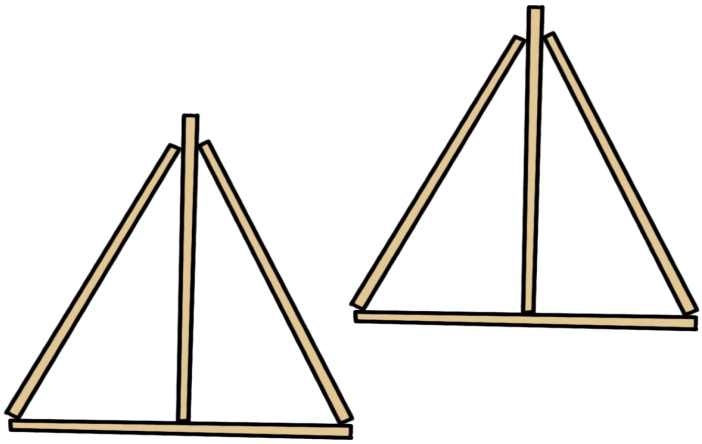




Step 1: Make a triangle with four popsicle sticks like below. Let the glue dry completely.



Step 2: Repeat step 1 and make another triangle



You can also use tape instead of a hot glue gun to connect the popsicle sticks

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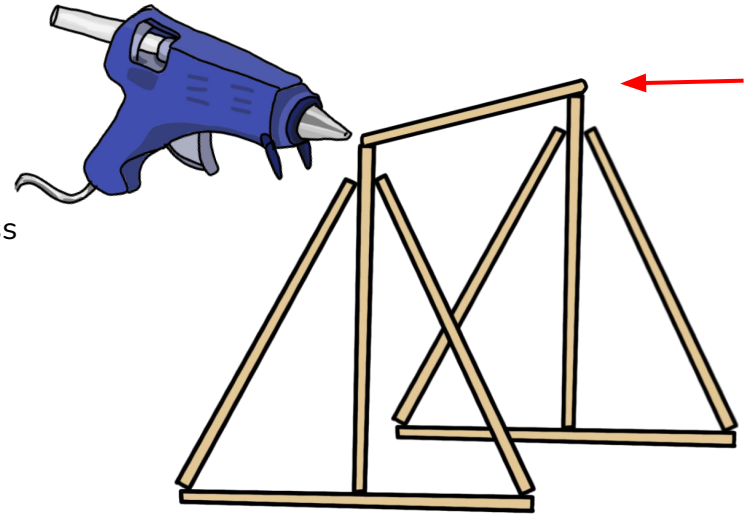
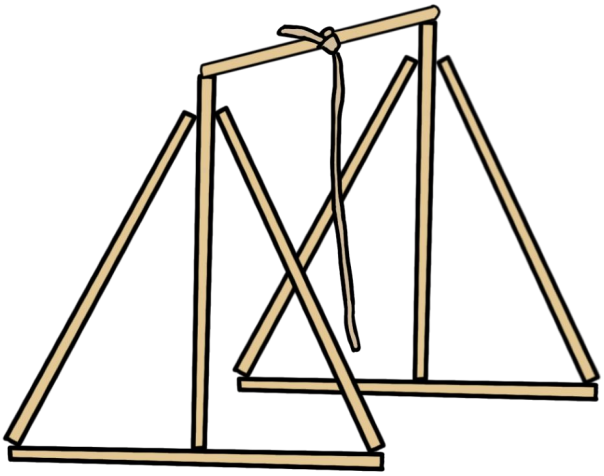
Step 3: Connect the two triangles together with a popsicle stick across the top. Glue together.

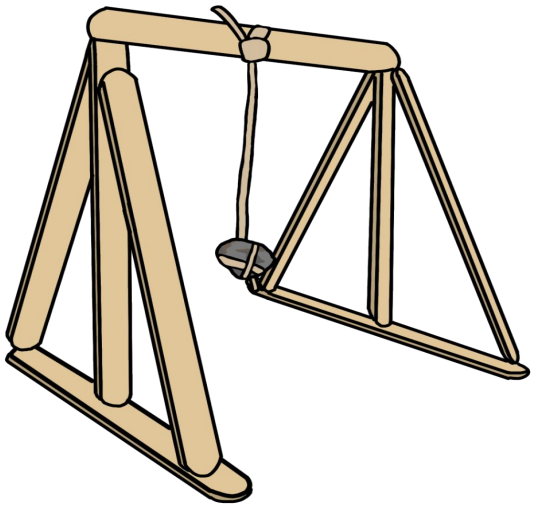


Step 4: Attach a piece of string to the top popsicle stick with a knot. The string should **almost** touch the ground.



Step 5: Tie one end of the string to the object you want to swing.

You can use any object for the weight, as long as it fits and not too heavy.

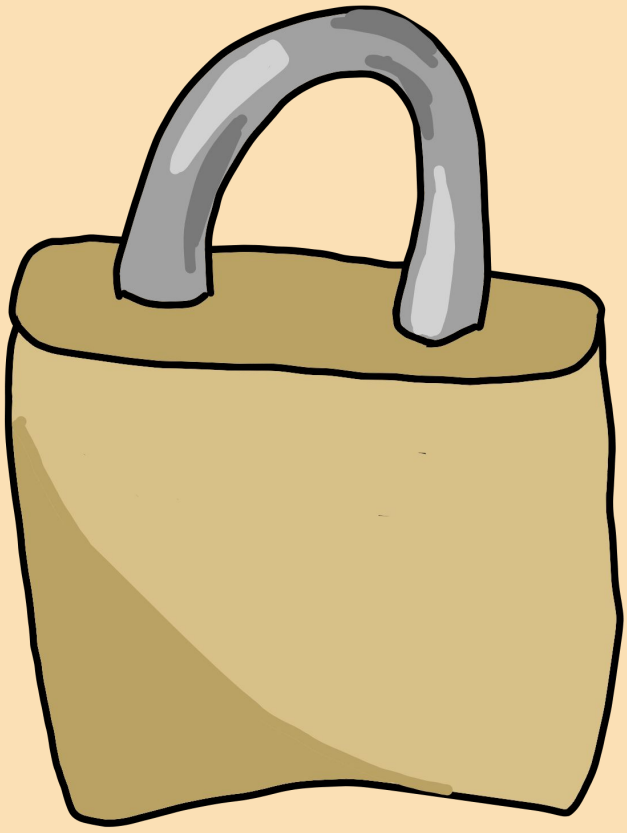


See it swing!


NEWS!


NEWS!

Locking mechanisms



Need a way to keep something from moving or opening?

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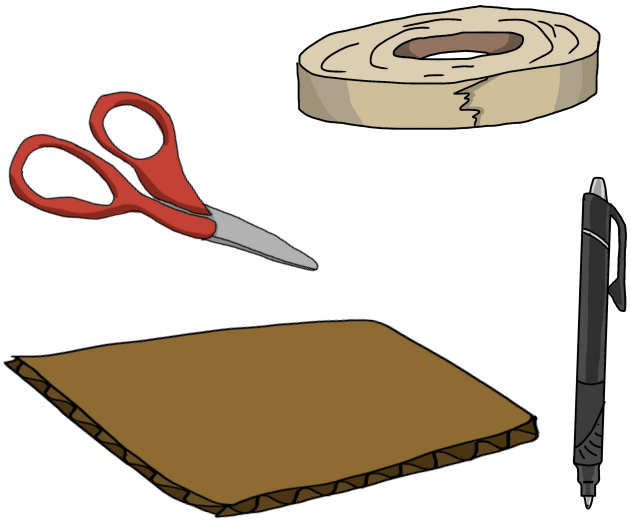
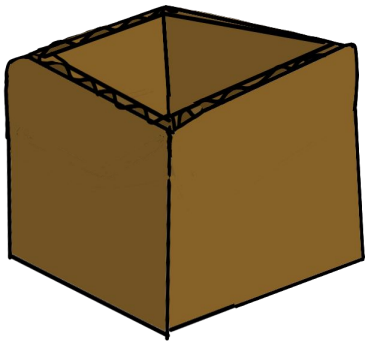
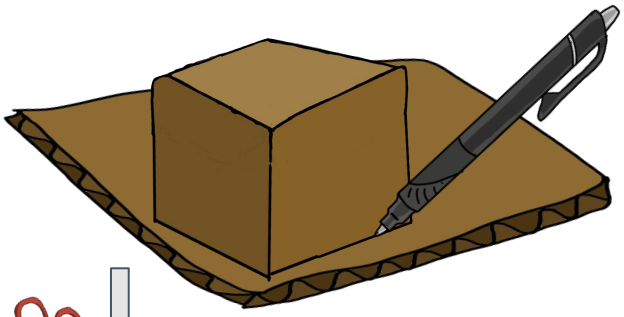
"Twist and Lift" Locks

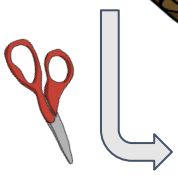


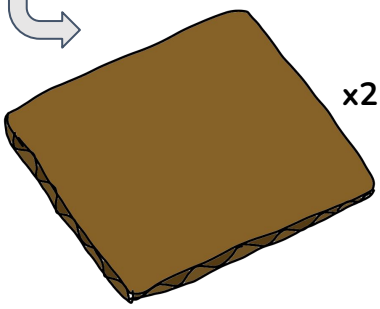


Something you want to make a locking lid for

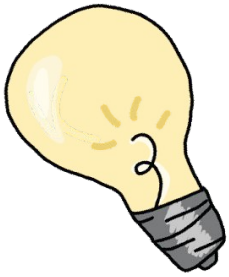
Step 1: Trace the opening of your box and cut out of cardboard twice. These are your lids.





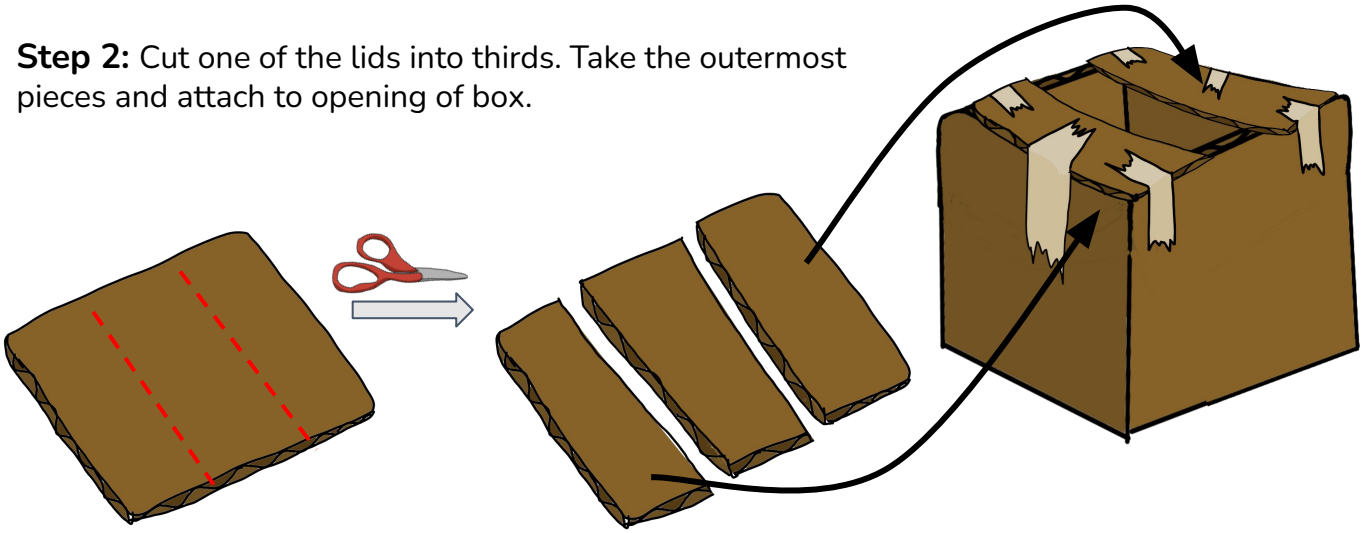


x2

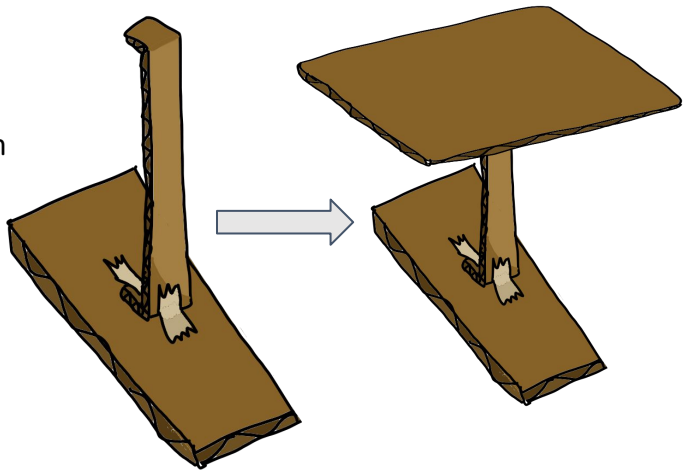


To make your project recyclable, substitute the tape for safety pins to hold pieces of cardboard together.

Step 2: Cut one of the lids into thirds. Take the outermost pieces and attach to opening of box.

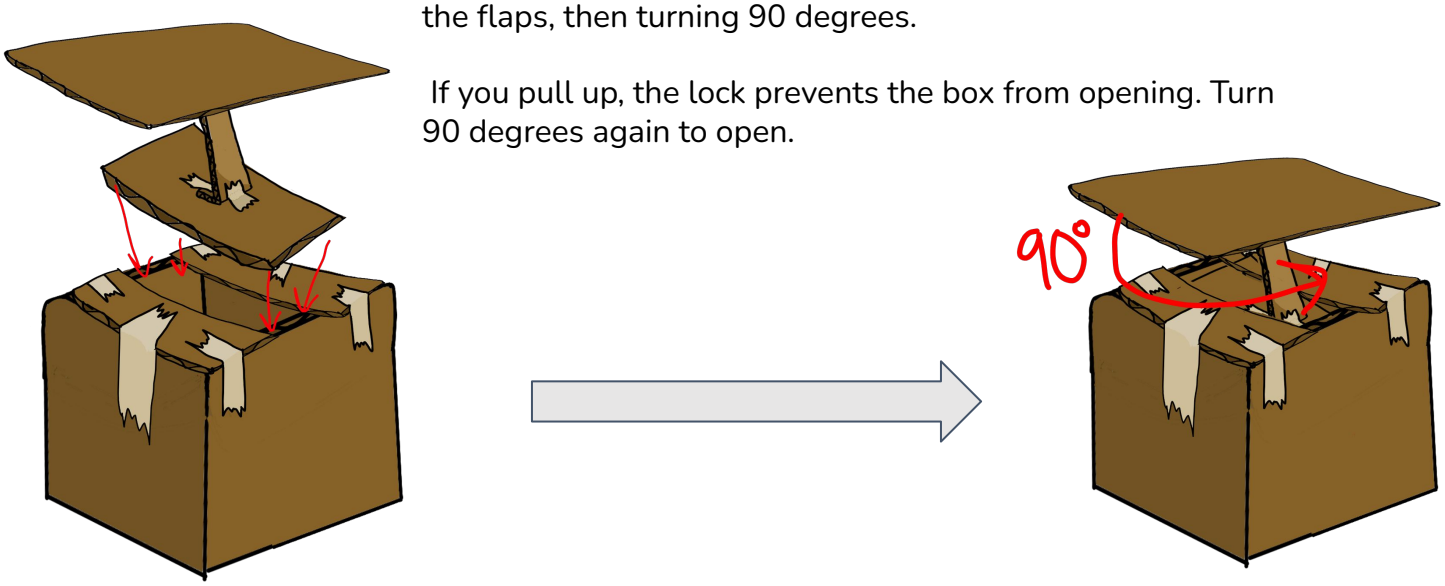


Step 3: Cut a small strip of cardboard. Attach one side to the middle piece of cardboard from Step 2 and the other side to the remaining lid.



Step 4: Lock the lid by lowering the rectangle in between the flaps, then turning 90 degrees.

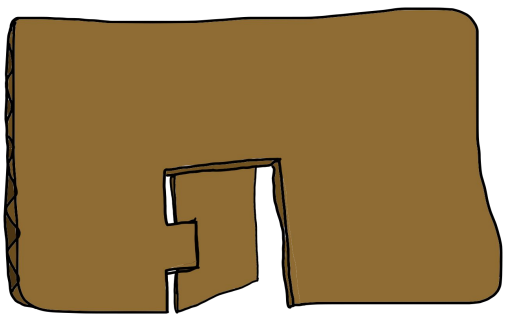
If you pull up, the lock prevents the box from opening. Turn 90 degrees again to open.

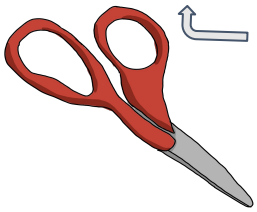


Watch the lock close!

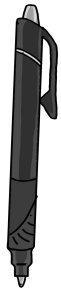
Watch the lock open!

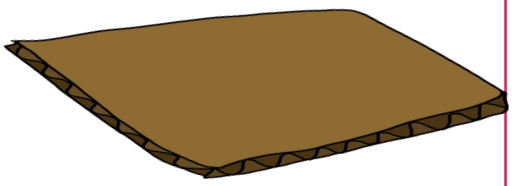
Sliding tab lock

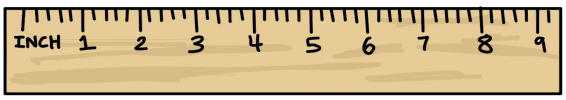




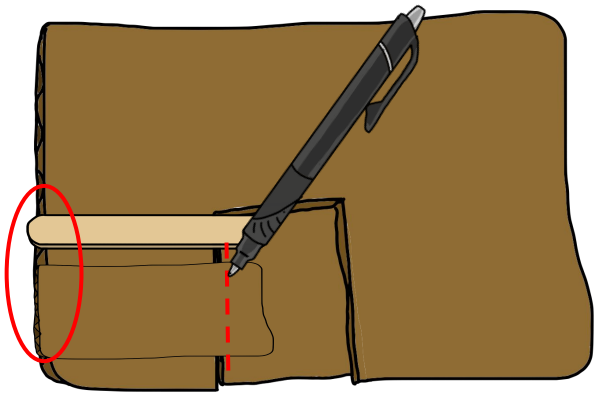
"door" hinge mechanism (page 70)



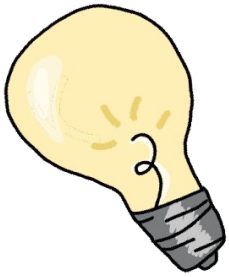




Step 1: Cut out a small rectangle of cardboard.



Step 2: Line up the cardboard and stick on the left edge, mark on both where they reach the hinge. Cut both at the mark.

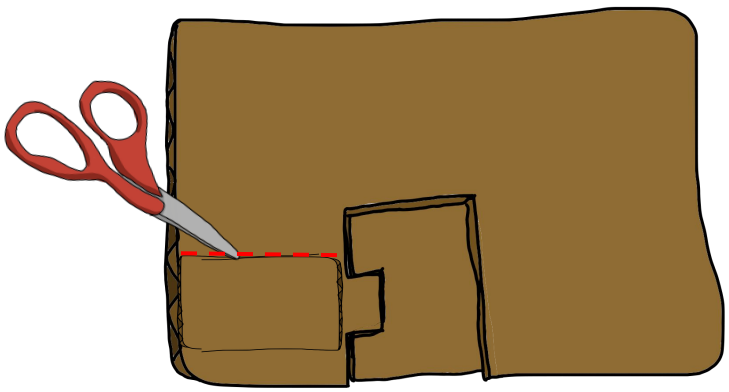


Anything sturdy and smooth, like a skewer, can replace the popsicle stick.

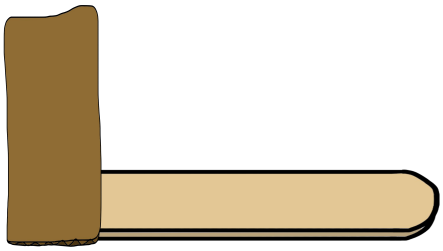
Use an X-ACTO knife for a more precise cut than scissors. Have an adult help!

Step 3: Glue the rectangle to the back so it is close but not touching the hinge.

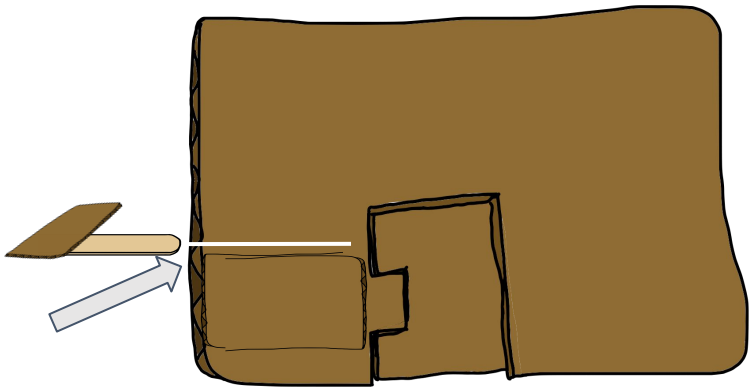
Step 4: Cut a line through the main wall right above the rectangular piece.



Step 5: Cut a small rectangular cardboard piece. Glue or tape to one of the sides of the cut stick.

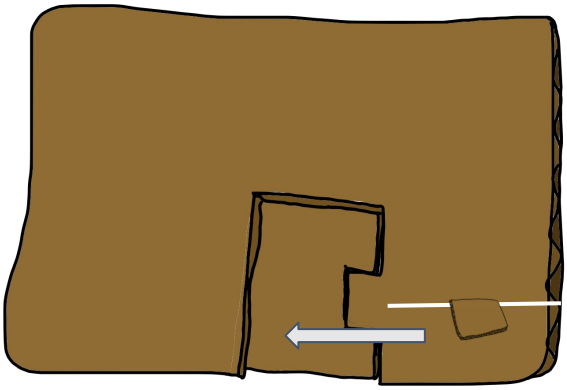


Step 6: Rotate the popsicle stick so the flat part faces up. Slide the small rectangle into the cut so it sticks out the other side of the wall. The stick should be resting on the large rectangular piece.

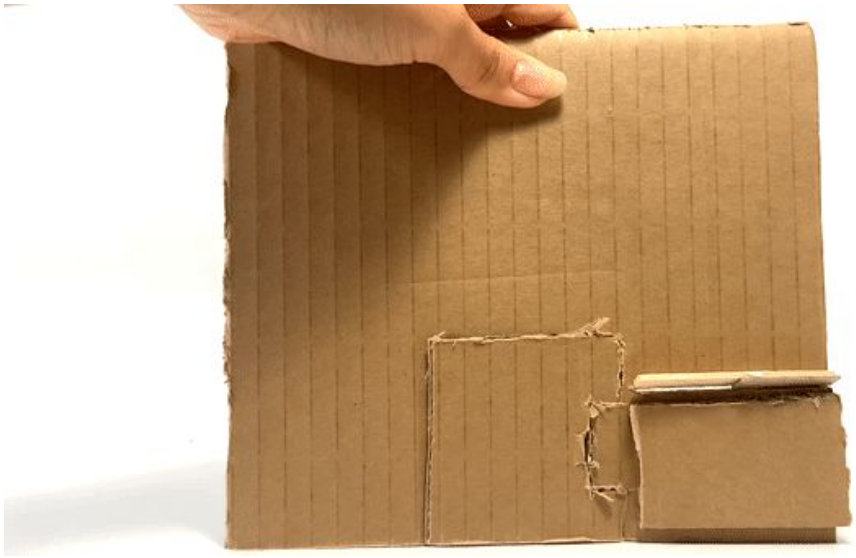


Step 7: Flip over. Lock the “door” by gripping the small cardboard flap and sliding towards the “door”.

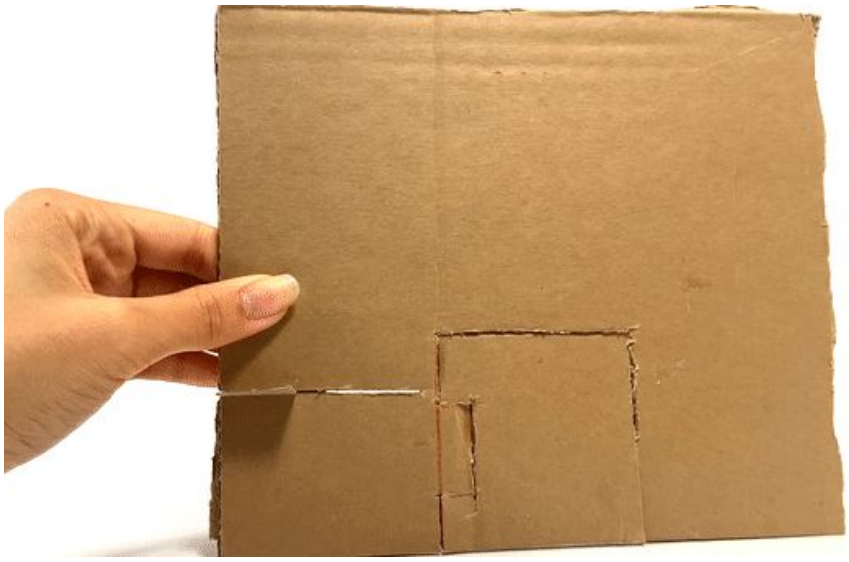
Now the stick blocks the door from opening.



How to slide the lock:

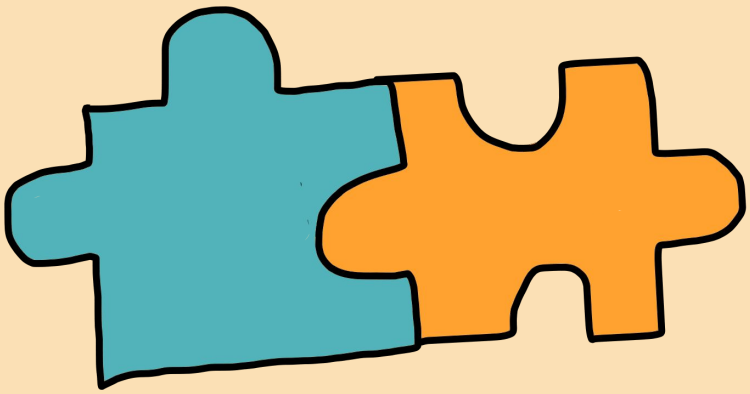


Watch the lock block the door!




NEWS!

Basic connections



Ideas for how to securely connect pieces.

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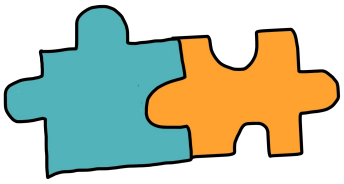
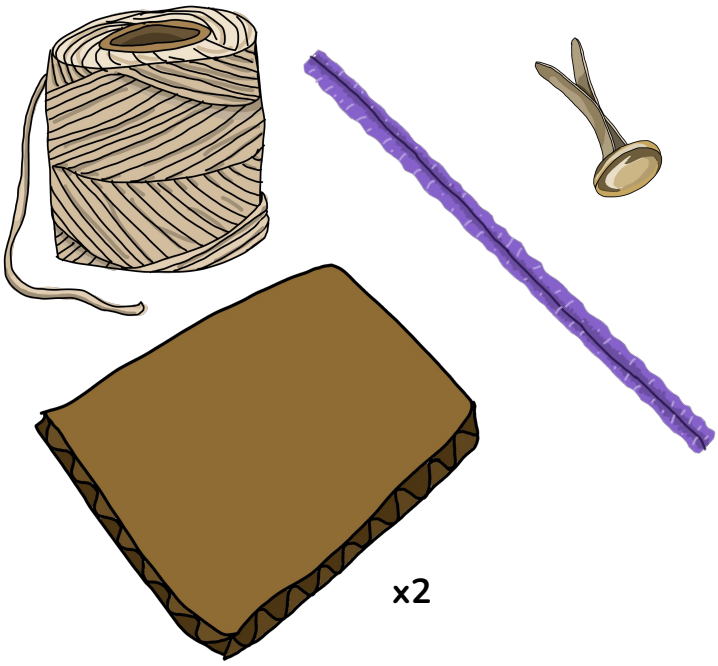
Pivoting connections



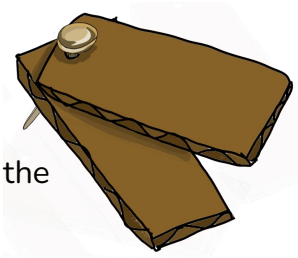


Step 1: Poke a hole through both pieces towards the edge of each piece.

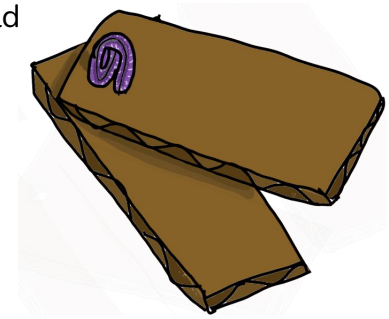
Step 2: Overlap the holes and:

A: Insert a brad.

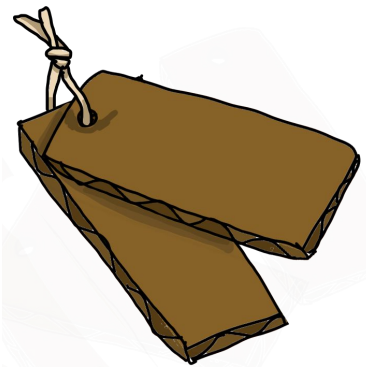
(Insert the legs through the hole, then pull apart)

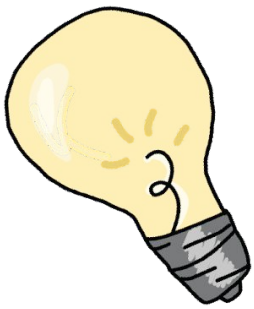


B: Insert a bit of pipe cleaner and make a spiral on both sides to hold in place.



C: Loosely tie a string through the holes.





Be careful when poking holes. Try using a pencil or pen.

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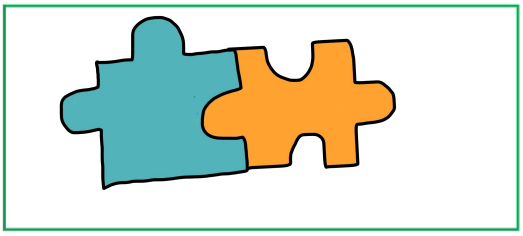
Option A

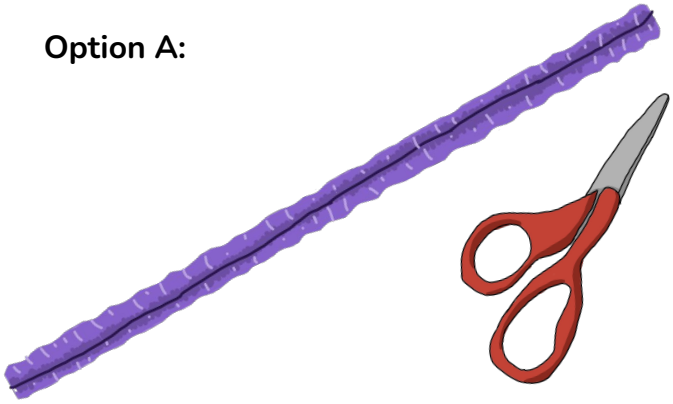
Option B

Option C

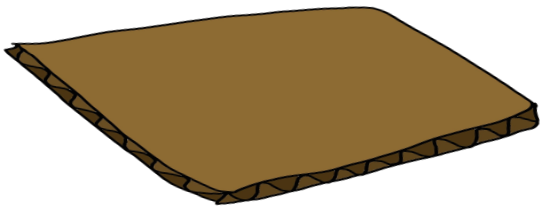
Bending connections



Option A:

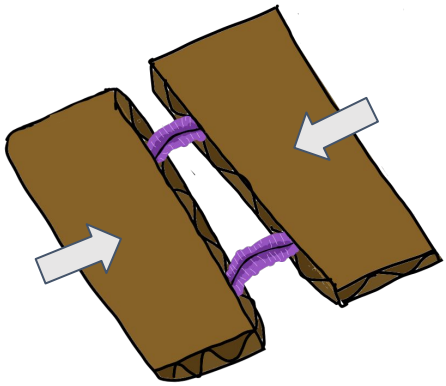


Option B:



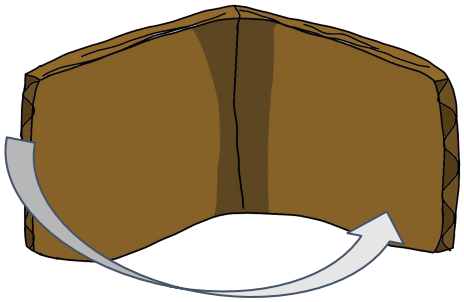
Option A:

Connect two pieces of corrugated cardboard by inserting pieces of pipe cleaner into the corrugation. Push the pieces together.



Option B:

Take a piece of cardboard and bend in half back and forth so the bend moves easily.



To make a bending connection for any material, tape a cardboard bending connection behind the 2 pieces of material.

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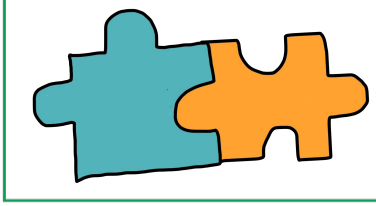
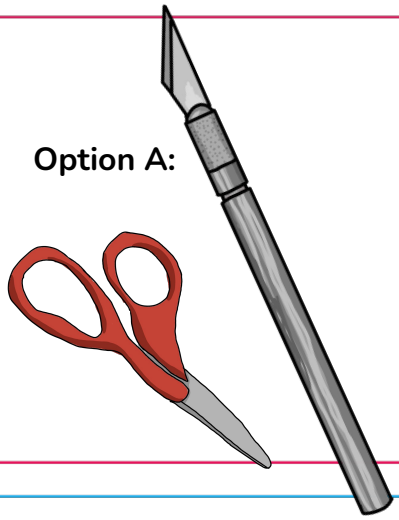
Watch it bend!

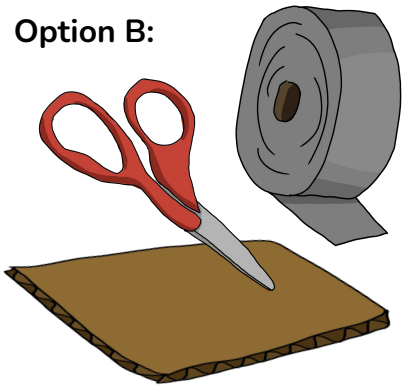
Connecting to Flat Cardboard



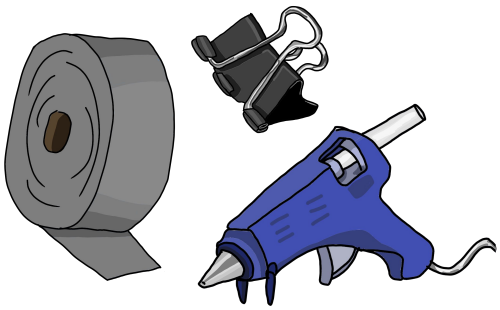
Option A:



Option B:

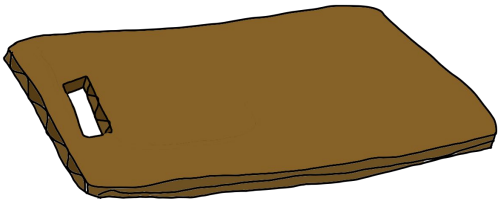


General suggestions:

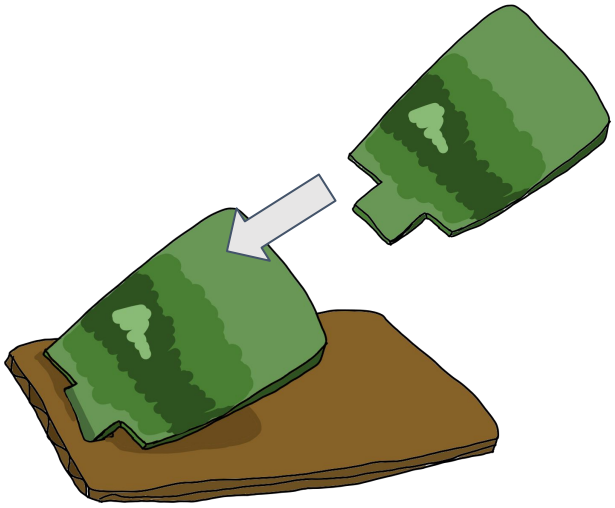


Option A (Tab method):

Step 1: Cut a rectangular slit in the cardboard.



Step 2: Cut a tab approximately the size of the slit into the part you want to connect. Slide tab into slit.



WARNING! You should have an adult help you with Option A.

For a tighter fit, make the tab slightly larger than the slit.

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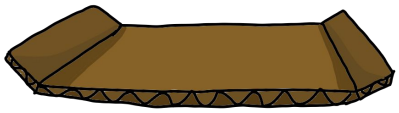
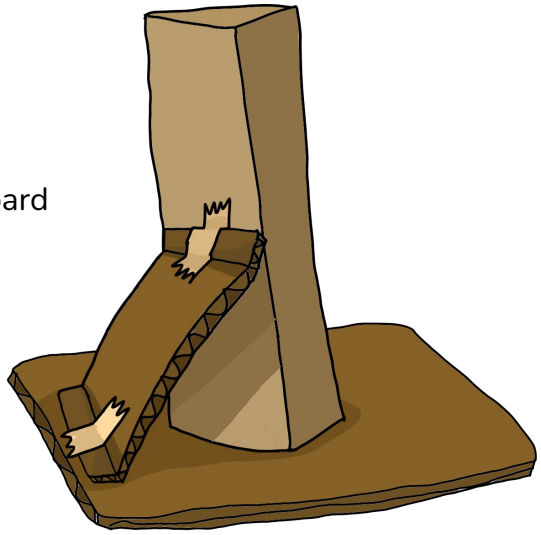
Option B (Support method):

Step 1: Cut a small piece of cardboard and bend at both edges slightly.



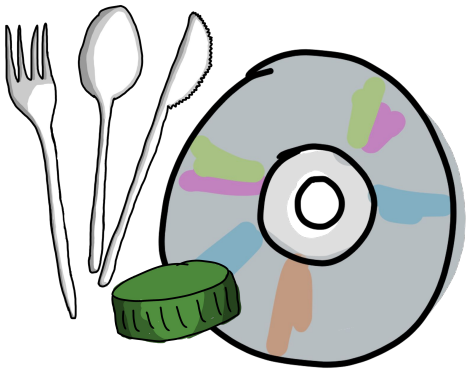
Step 2: Duct tape or hot glue one edge to the cardboard and the other edge to the piece you want to connect.



General suggestions for connecting different types of materials to cardboard

For plastic:

- hot glue gun
- duct tape
- tab method
- support method

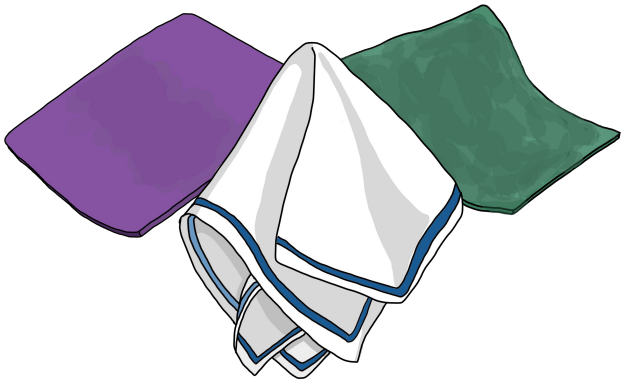


For cardboard or paper:

- hot glue gun
- duct tape
- binder clips
- tab method
- support method

For fabric, felt, foam:

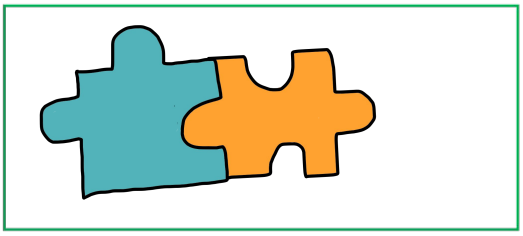
- hot glue gun



Tab Method

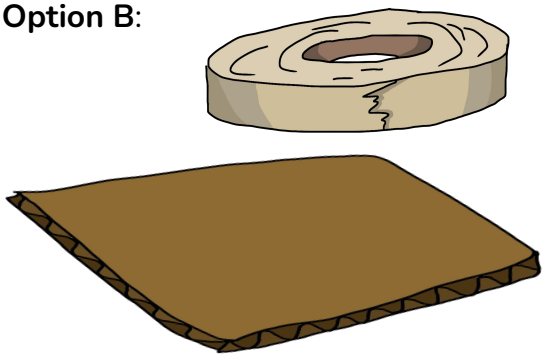
Support Method

90° CONNECTIONS

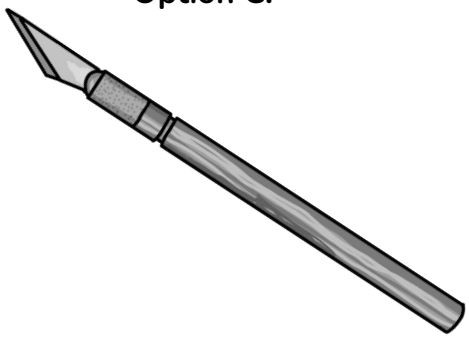


Option A:

Option B:

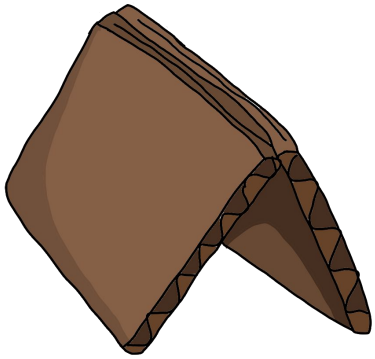


Option C:

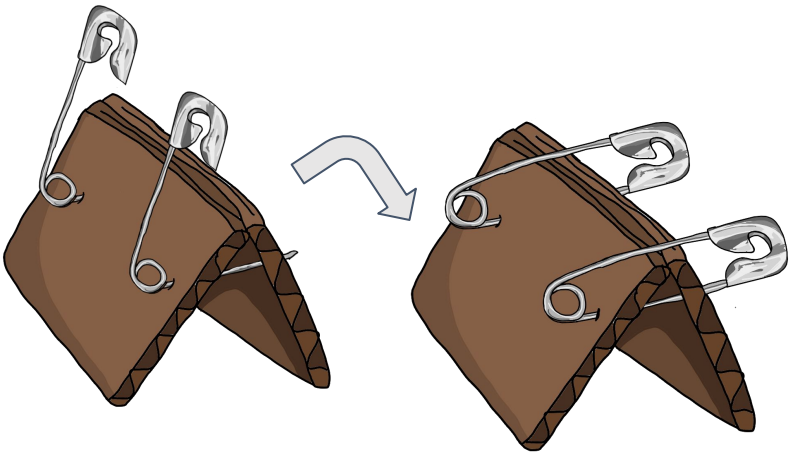


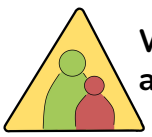
Option A:

Step 1: Hold the two pieces with the edges together like a tent.



Step 2: Carefully poke safety pins through the top of the tent and close the pins.





WARNING! You should have an adult help you with Option C.

Options A and C work best for cardboard, Option B works for any materials.

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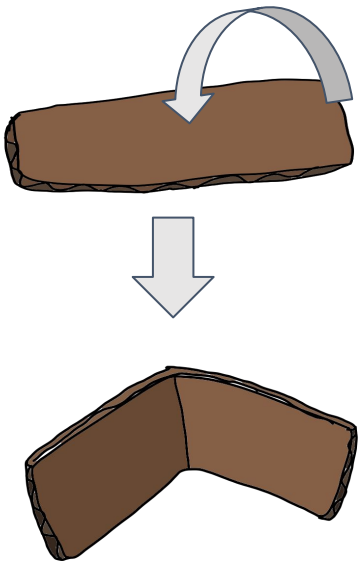
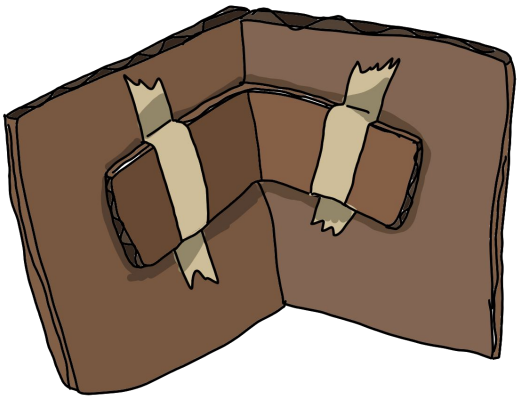
Option B:

Step 1: Cut out a small piece of cardboard and bend in half.



Step 2: Hot glue or duct tape one side to a piece and the other side to the other piece.



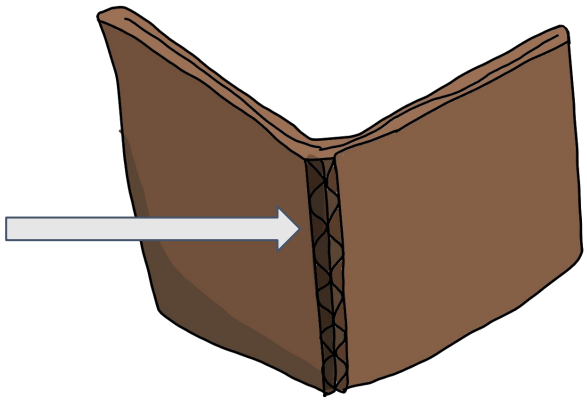
Option C:

Step 1: Score the cardboard down the middle.

(Scoring means to lightly cut through the top layer of cardboard)

Step 2: Fold to 90 degrees so the scored edge points outwards.

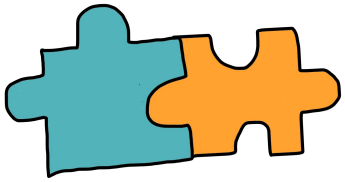
this is the scored edge

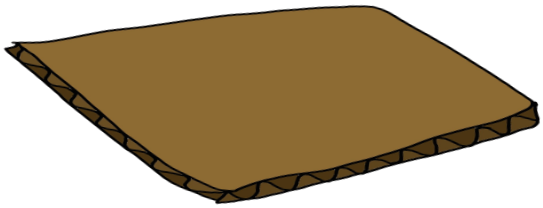


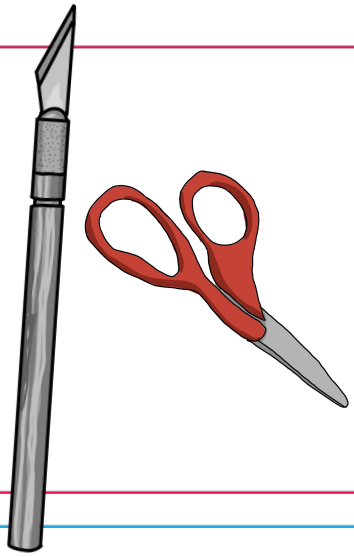
Option A: Safety Pins

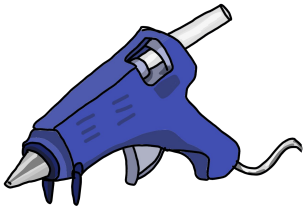
Option B: Tape

Removable connections



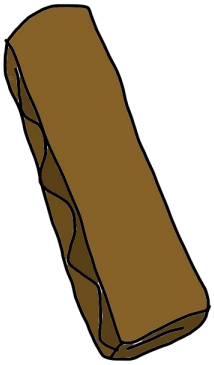






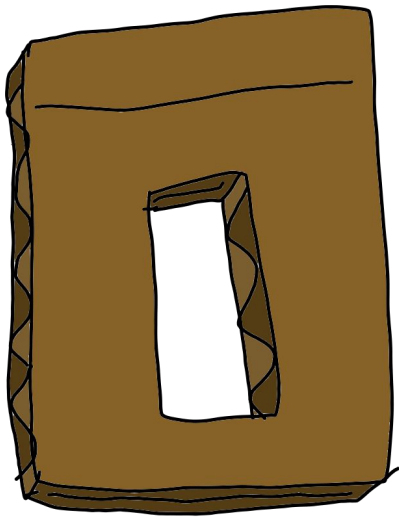
Option A: Latch

Step 1: Cut a strip of cardboard around 2-3 inches long.



Step 2: Bend the strip into an arch.

Step 3: Get a different piece. Crease a fold at the top. Cut a rectangle the width of the strip in the middle



To make a removable connection with any materials, just hot glue or tape these pieces to the desired materials.

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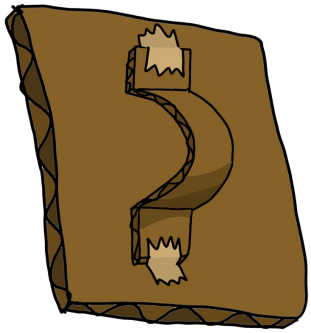
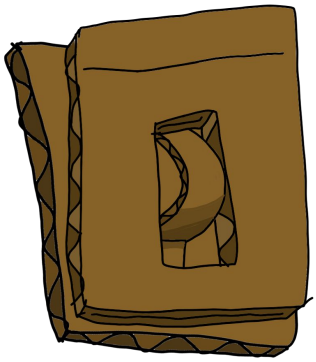
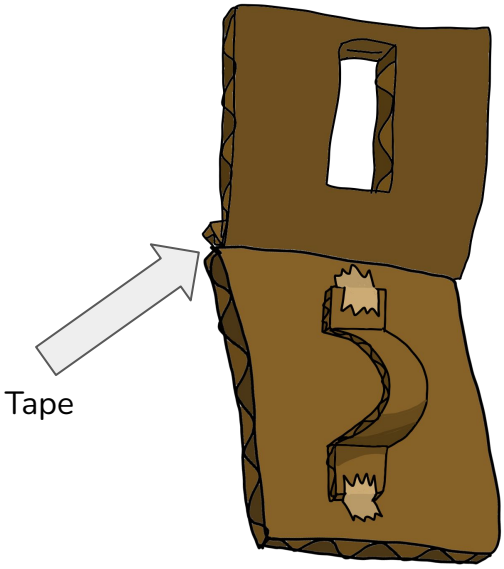
Step 4: Tape or glue the arch onto desired piece.



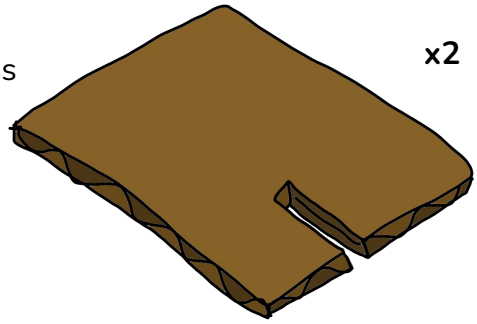
Step 5: Make sure the arch fits tightly in the rectangular hole. Tape the two pieces of cardboard together at one end. This is now your latch.



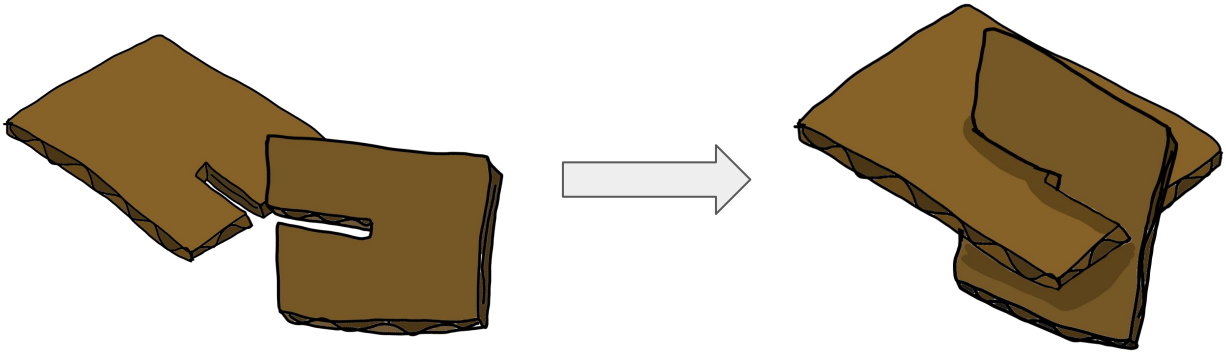


Option B: Notches

Step 1: Cut a slit the width of the cardboard's thickness in two pieces of cardboard.

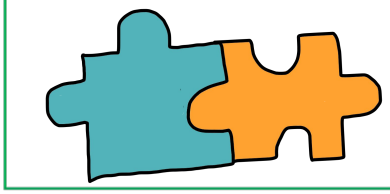


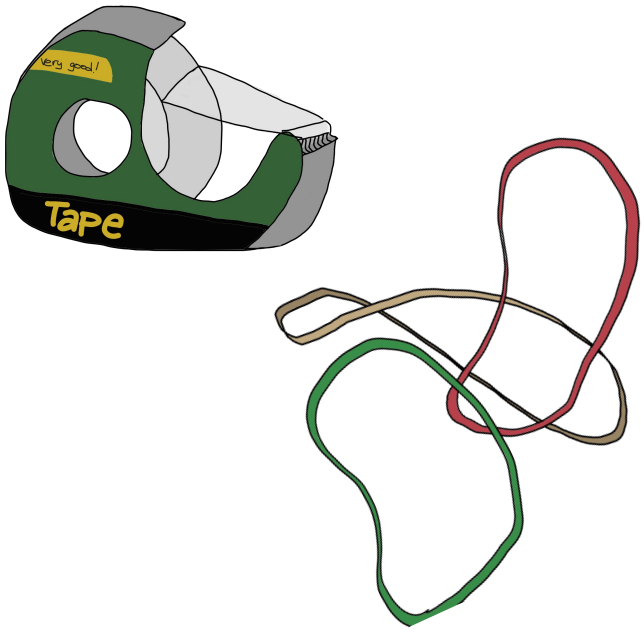
Step 2: Slide the notches together at a 90 degree angle.



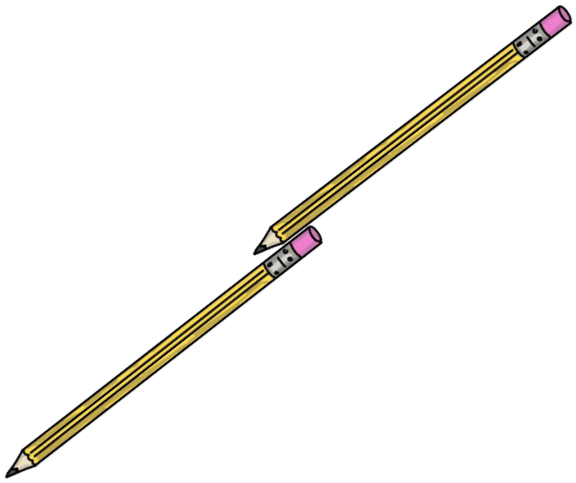
Watch how the latch works!

Making something long



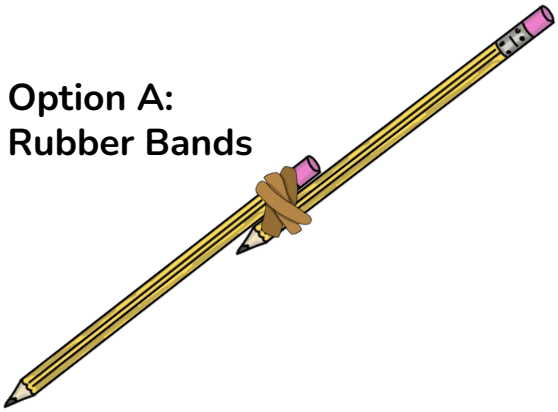


Step 1: Hold the two pieces slightly overlapped.

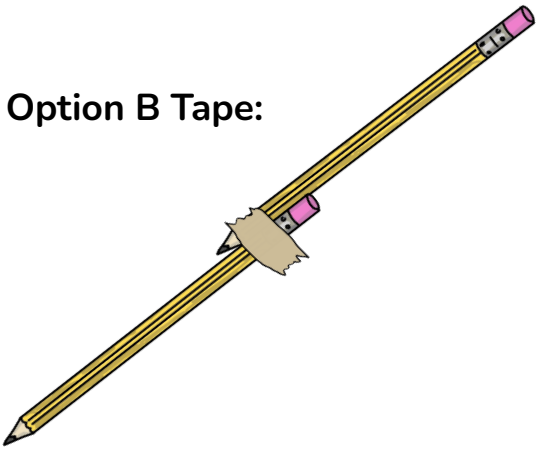


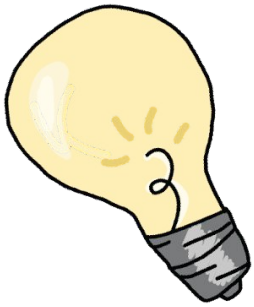
Step 2: Rubber band or tape together.

Option A:
Rubber Bands



Option B Tape:





Repeat process with as many pieces as you want! The more overlap, the stronger the connection.

A NOTE FOR EDUCATORS

Hello! This Constructopedia is designed to help you help your students. Here's how:

These instructions are designed to help students with basic mechanisms so that they can build more complex projects.

This should allow them to think more creatively when approaching design challenges

We want students to be focusing on their design, not stuck on how to make something move or connect!

You can use this document and refer students to specific instructions if you see they are struggling with some mechanism.

This will help you manage a classroom of students working on multiple projects more easily.

Have students peruse through and get inspiration for mechanisms in their project.

It may help students with building challenges if they understand what building blocks are available.

Possible recyclables to collect for use:

- *Cereal boxes/tissue boxes*
- *Plastic containers*
- *Toilet paper tubes / paper towel tubes*
- *Popsicle sticks*
- *Scrap paper*
- *Newspaper*
- *Bottlecaps*
- *Egg cartons*
- *Cardboard*

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Thank you to all the folks who worked on the Constructopedia: Anne Hu, Richie Ng,