



Materials Required

This trebuchet is intended to be made mainly out of basswood strips, 1/4" x 1/2". This is readily available in most hobby stores in assorted lengths, most commonly 24". As such, the list below is based on 24" lengths, but any other stock length is fine, you will just need to figure out the correct quantity on your own by looking at the components shown later in the Construction section. Some other materials are needed, so the complete list is below. Most items can be found at hobby stores.

Quantity	Description	Approx. Cost (Total)
12	1/4" x 1/2" x 24" Basswood/Spruce Strips	\$15
1	1/16" x 3" x 36" Balsa Sheet	\$3
1	1/8" dia. x 12" Aluminum or Steel Rod	\$1
3	6-oz pack lead weights	\$10
/3	Small screw eyes	\$0.50
1	Steel-based paper clip	\$0.01
1	1mm dia. x 24" string	\$0.10
1	Scrap of tough fabric (denim or the like), 1.5" x 3.5"	\$0.01

So the total for this machine is around \$20 total (minus the weights which you might already have - you can use coins in a pinch, they just weigh less), but it is a very sturdy little machine. Instead of buying all the 1/4" x 1/2" material, a small sheet of 1/2" plywood can be ripped into 1/4" wide strips if desired. Cutting the individual parts will be a bit tougher, but is still doable with hand tools.

Tools Required

Some tools are needed as well as some glue and such.

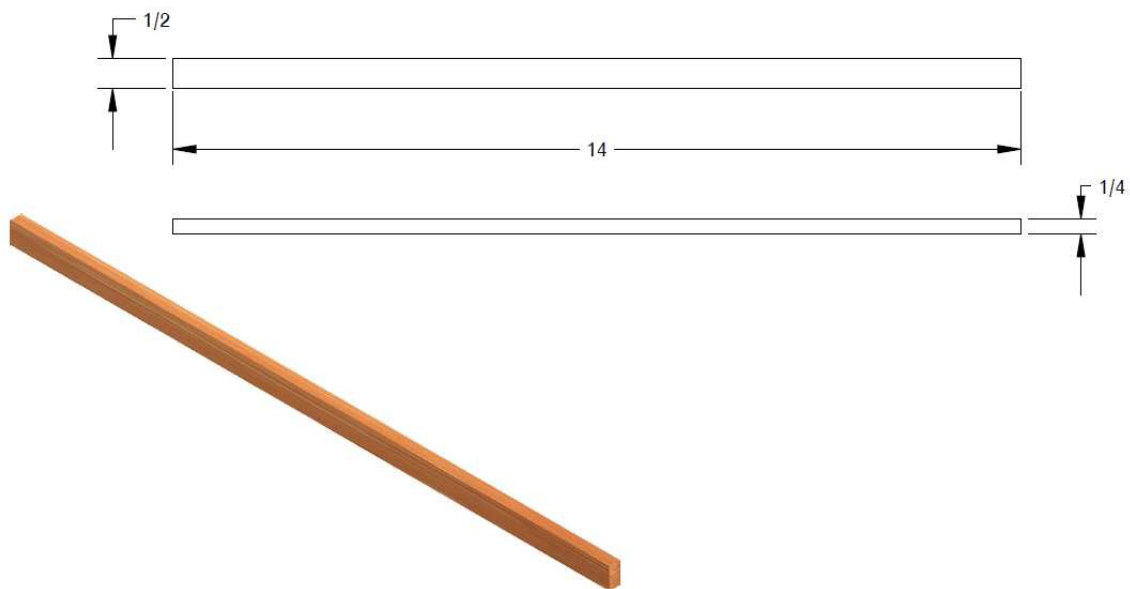
- Ruler - for measuring cut lengths of course!
- Glue - for fastening the joints, Elmer's Wood Glue works great for this
- Clamps - for holding joints together, large binder clips work great
- Drill/Drill press - for drilling a few holes, a drill press is recommended so the holes are square
- 1/8", 3/64", 1/16" Drill Bits - for drilling some holes
- Saw - for cutting pieces, a power saw is okay, but a modeling handsaw and miter box works best for the small pieces as large saws tend to throw tiny pieces
- Small Protractor - for measuring a couple non-right angles

CONSTRUCTION

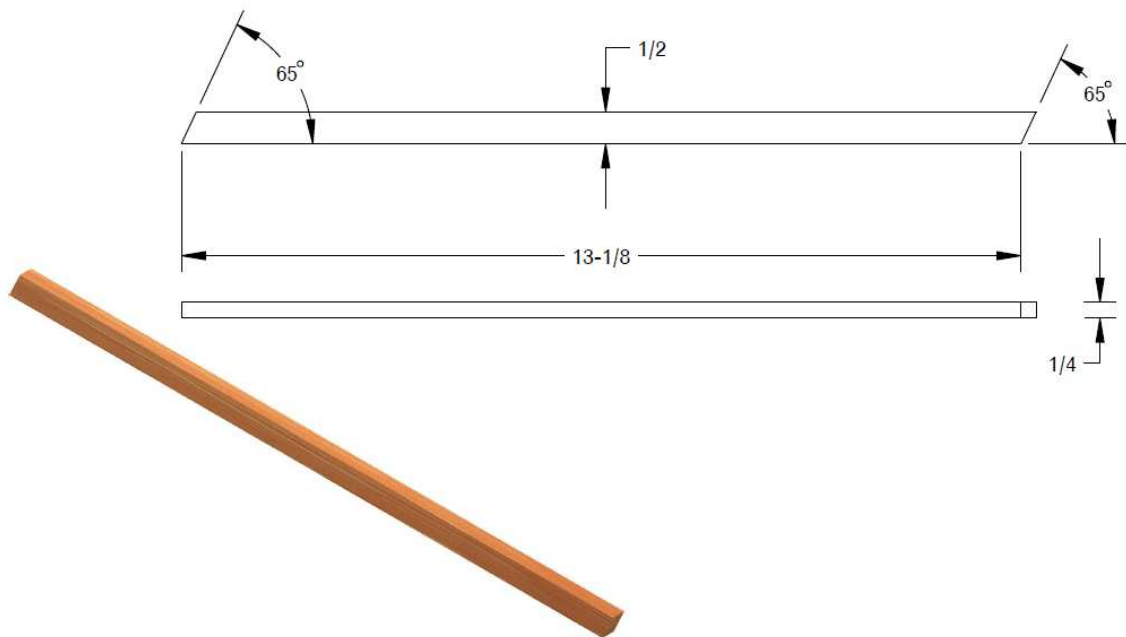
A-FRAMES (2 of them)

The first thing that needs to be made is the pair of a-frames that form the body of the machine. Cut out the parts below, the total quantities needed are indicated in parentheses -- i.e. base (x2) means to cut two of these parts as indicated. All parts are out of $\frac{1}{2}$ " x $\frac{1}{4}$ " stock, cut across the wide face as shown.

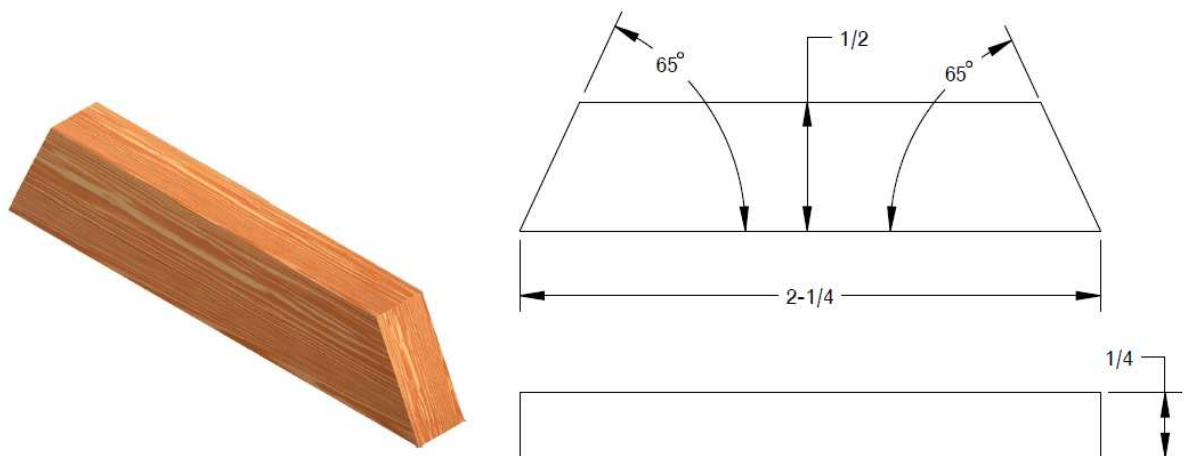
Base (x2)



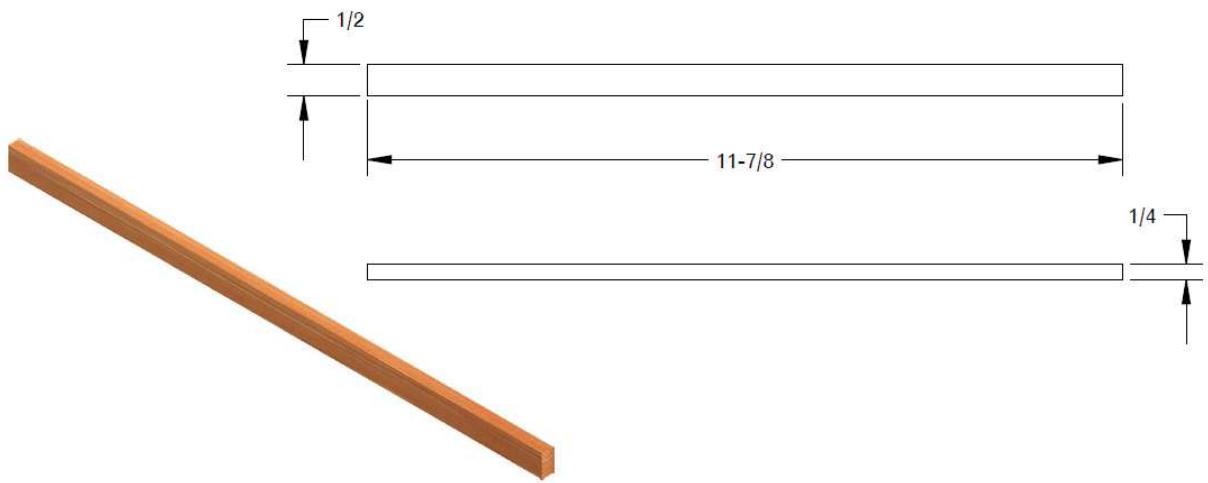
Leg (x4)



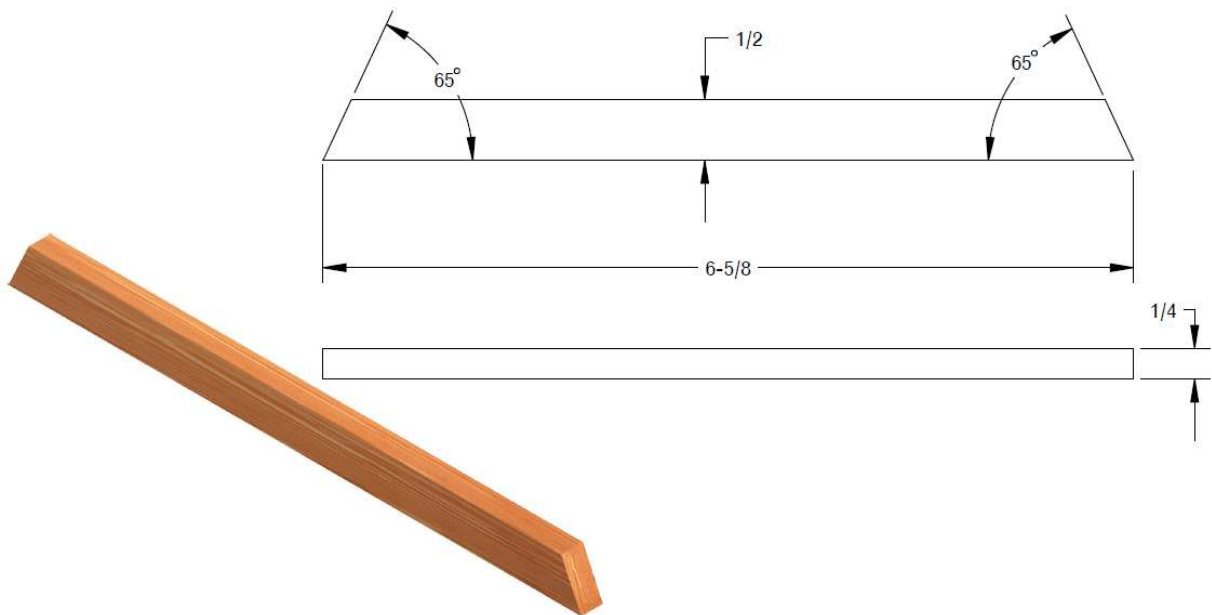
Frame Cap (x2)



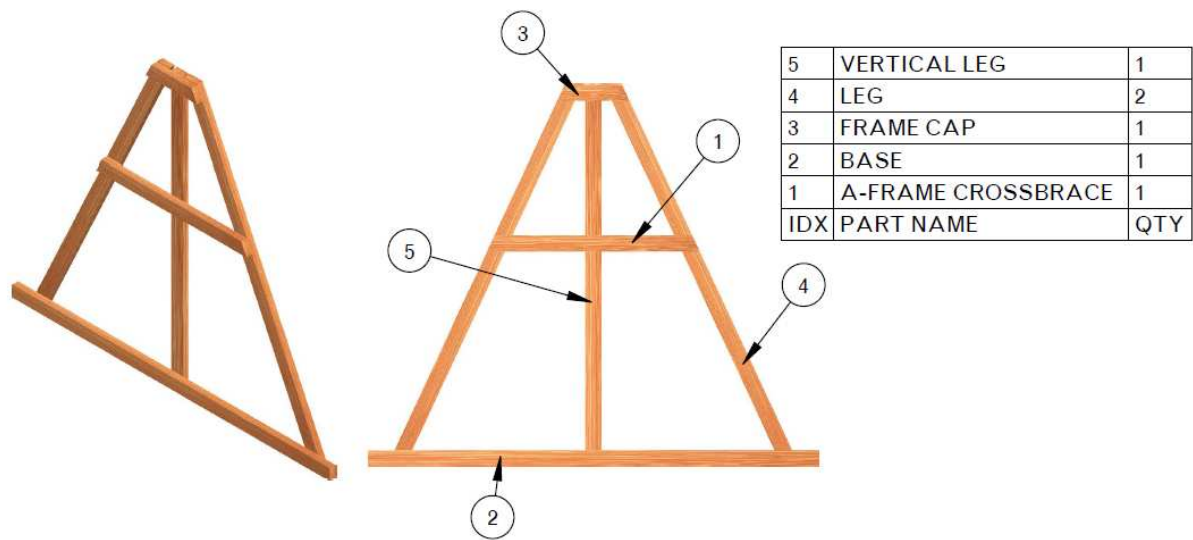
Vertical Leg (x2)



A-Frame Crossbrace (x2)



Then assemble the pieces as shown below. Glue together the pieces at all joints, and clamp for the necessary time if using wood glue, or other glue that needs time to cure. Assemble the first frame completely, and assemble the second one on top of it, ensuring that all components line up between the two frames. Particularly, the base and frame caps need to be aligned correctly with each other; otherwise the trebuchet may not function properly.

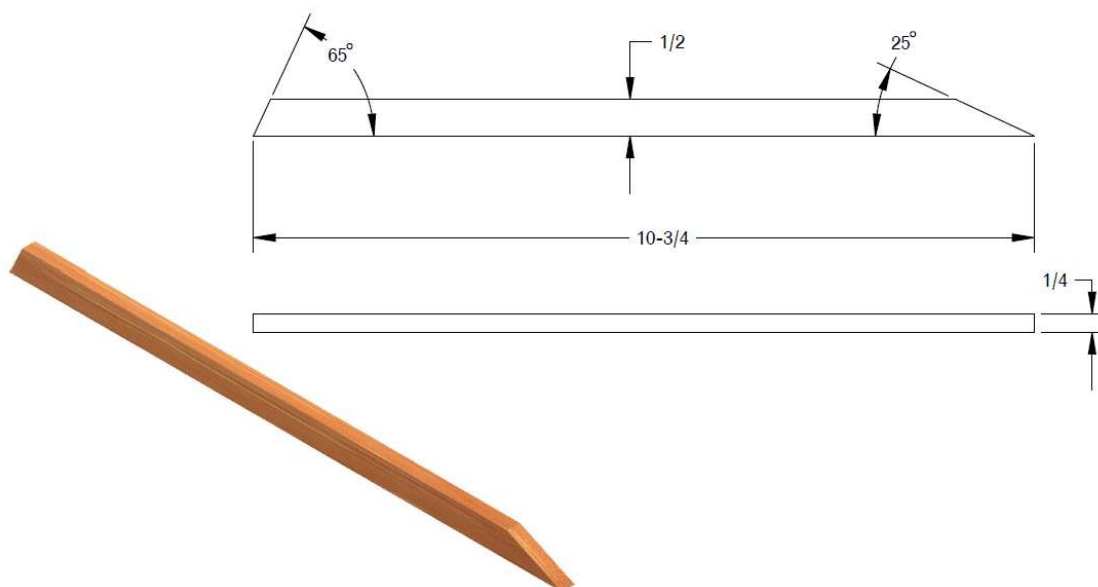


When you are done with these, you should have two identical (or nearly) a-frames.

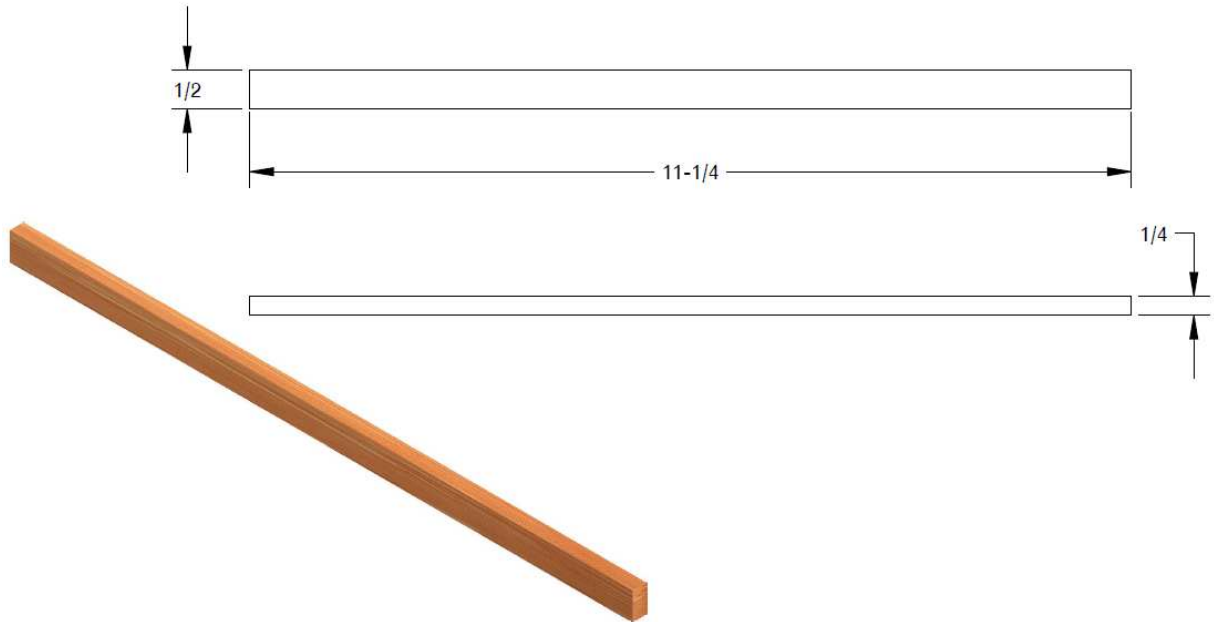
OUTRIGGERS/BASE

Next cut out the crossbraces and outriggers which will complete the frame assembly. Cut out the parts below, again noting the quantities in parentheses. As before, all pieces are 1/2" x 1/4" stock, cut across the wide face.

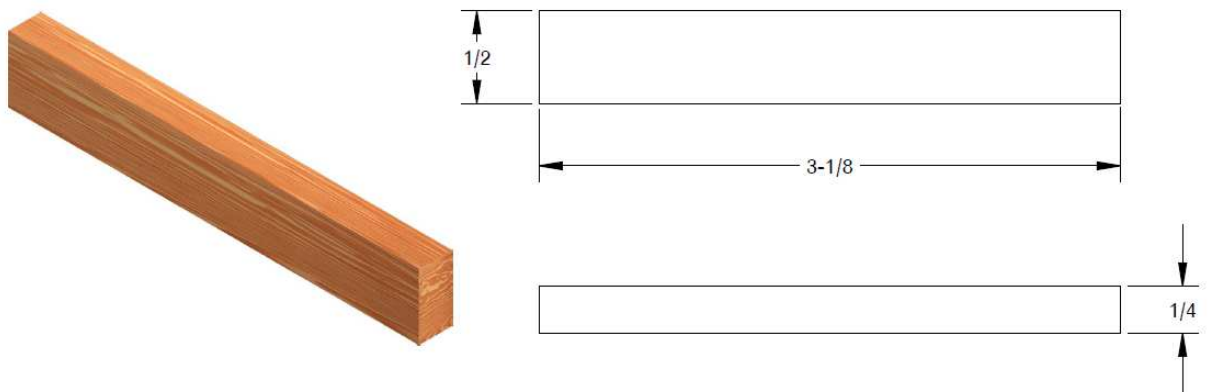
Outrigger (x4)



Outrigger Base (x1)

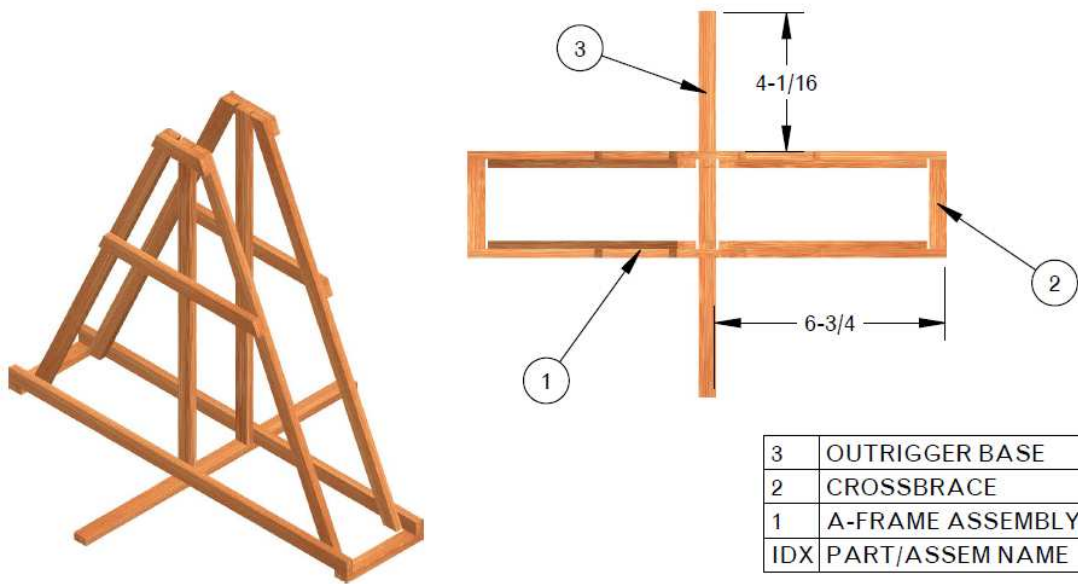


Crossbrace (x2)



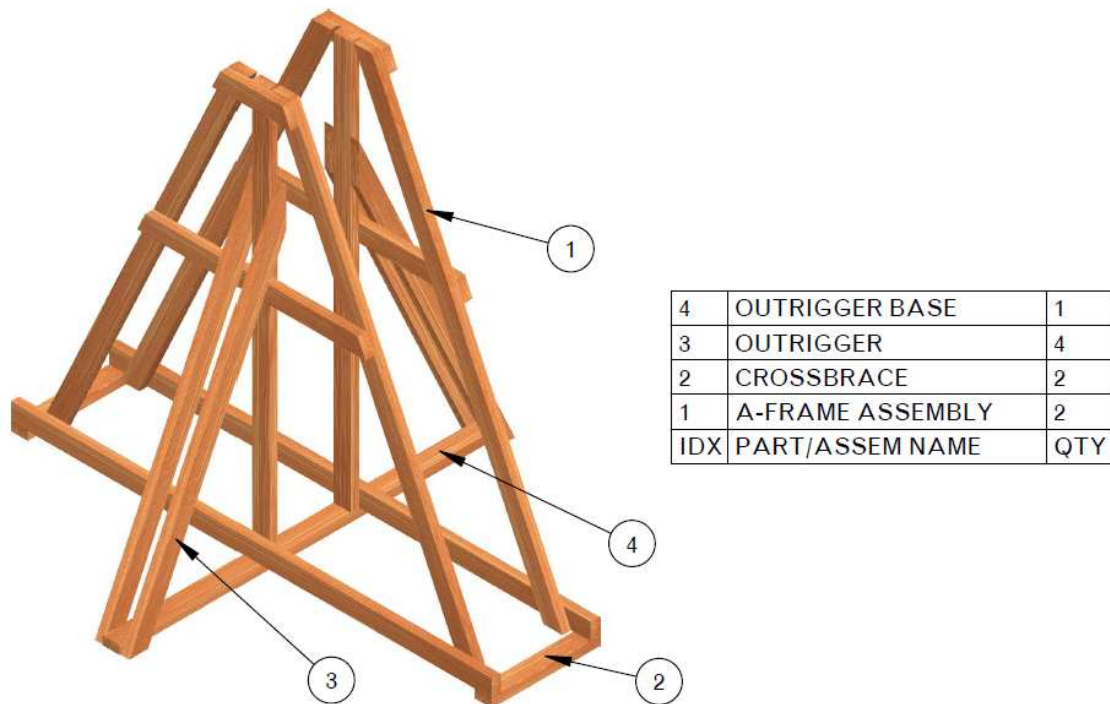
FRAME ASSEMBLY

After these are cut, attach the crossbraces and outrigger base as shown below. Note that the outrigger crossbrace should be centered both lengthwise and side-to-side along the a-frame bases (the dimensions shown are to guide you).

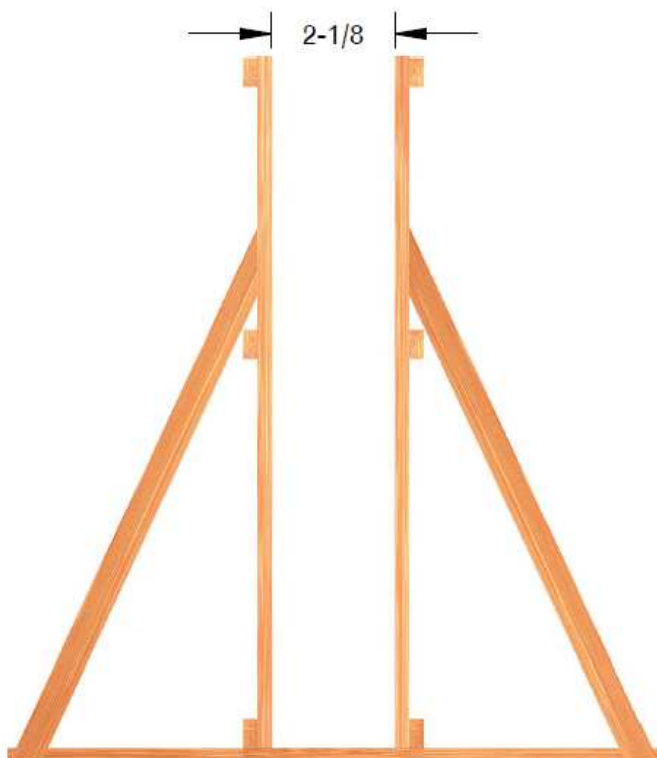


After the glue has dried (using clamps if necessary), glue an outrigger on one side of the outrigger base on one side of the frame as shown below. Make sure that the a-frame is standing square to the base before gluing and/or clamping. Repeat on the other side of the frame and then attach the other two outriggers on the opposite side of the outrigger base.

IMPORTANT: The a-frames need to be perpendicular to the base when clamping the outriggers for glue drying. If they are not square, the counterweight may not swing through properly, causing the trebuchet to not operate correctly, if at all.

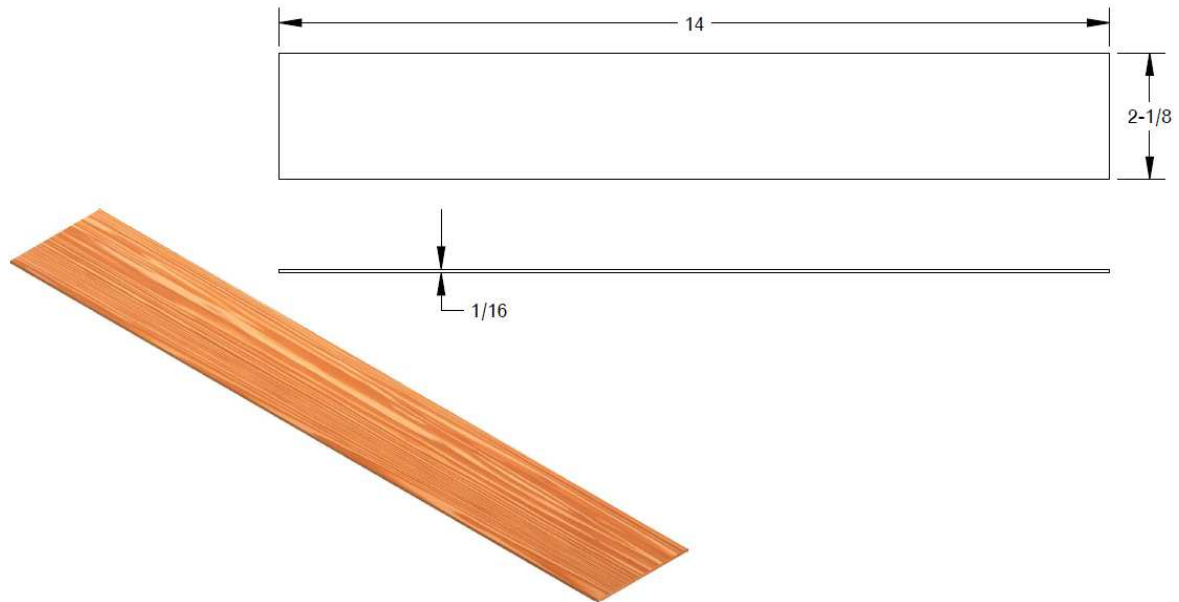


Once the glue has dried, you should have a completed frame to your trebuchet. The gap between the tops of the frame should be roughly $2\frac{1}{8}$ ". If it deviates from this by more than $\frac{1}{4}$ " on either side (that is, the gap lies outside the range of $1\frac{7}{8}$ " -- $2\frac{3}{8}$ "), check the a-frames for square to the base again, and reposition the outriggers on the vertical brace as necessary (which will require breaking the old glue bond and re-gluing).



TROUGH

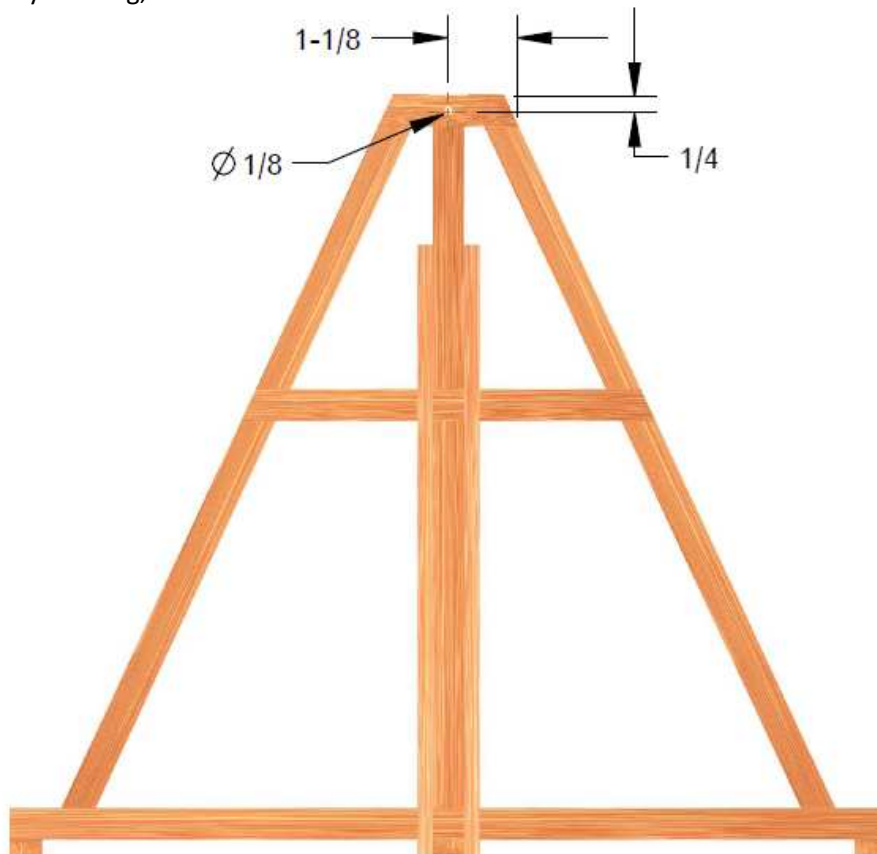
Cut out a piece of 1/16" thick balsa sheet for the trough per the dimensions below.



Glue this piece onto the base of the machine across all three crossbraces, as shown below.



Place a 2-1/8" long piece of scrap between the tops of the a-frames and clamp (no glue) this piece into position. This is merely a trick to help drill the hole; you can try something else if you have a different idea on how to keep the frames in line. Drill the 1/8" hole as shown with a drill press to ensure the hole is straight. This hole needs to pass through both frames. After it is drilled, remove the clamp and spacer block and test-fit a length of 1/8" rod through the holes. The rod should slide in without needing to be bent, if this is not the case, slightly enlarge the holes until this is the case. It does not need to be freely rotating, however.

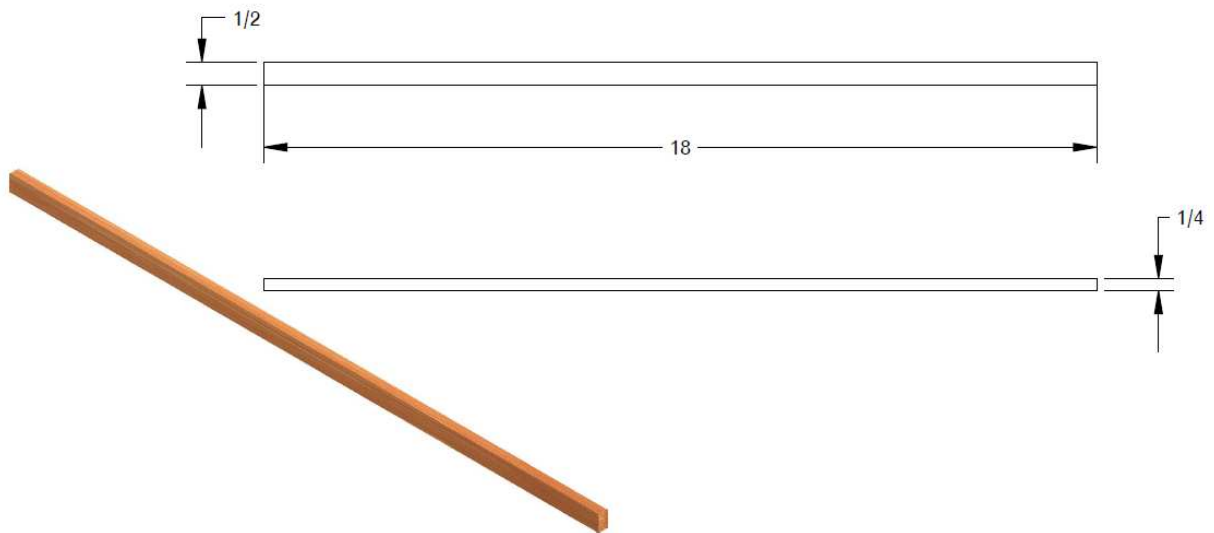


That's it, you now have a completed trebuchet frame ready to go!

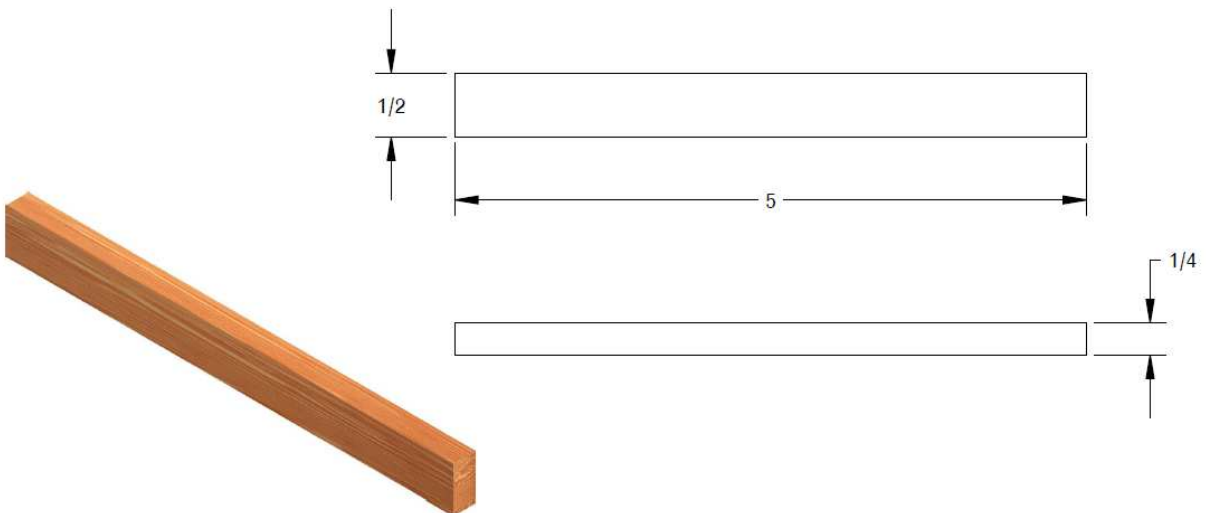
THROWING ARM

Now cut the pieces for the throwing arm out of more 1/2" x 1/4" stock as shown below.

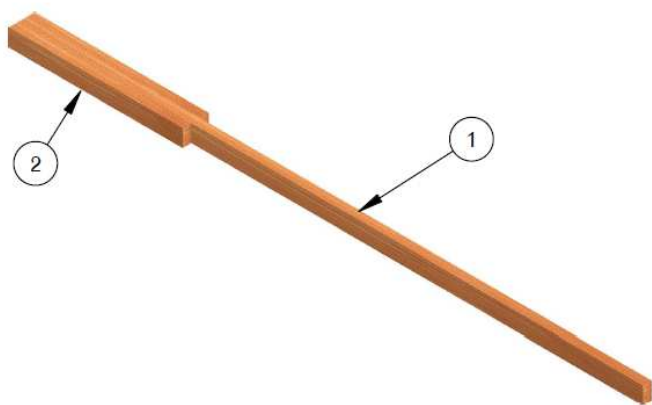
Main Arm (x1)



Short Arm (x2)

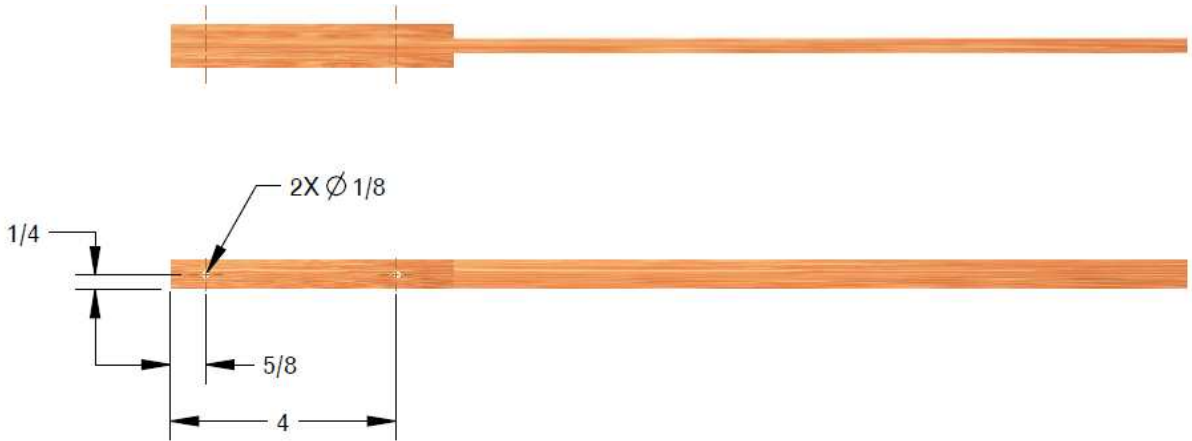


Assemble (glue) the pieces as shown, one short arm on each side of the main arm.

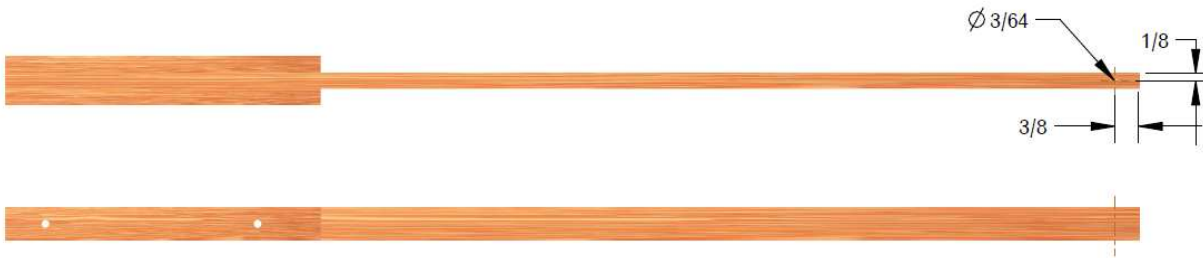


2	SHORT ARM BEAM	2
1	MAIN THROWING ARM BEAM	1
IDX	PART NAME	QTY

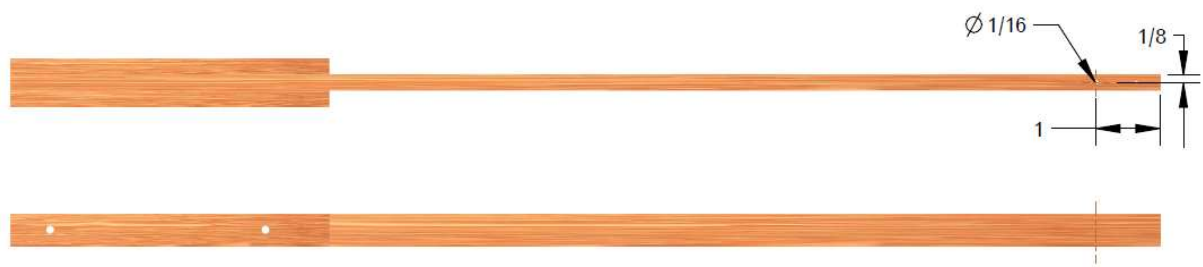
Then drill two 1/8" holes using a drill press in the locations indicated below. Test-fit a piece of 1/8" rod through the holes, it should turn freely but not be too sloppy. Slightly enlarge the hole if necessary to get the free rotation.



Drill a 3/64" hole through the 1/4" wide side of the arm as shown below, and then insert a small screw eye into it.



Drill a 1/16" hole through the entire arm from in the position indicated below (similar to the previous hole).

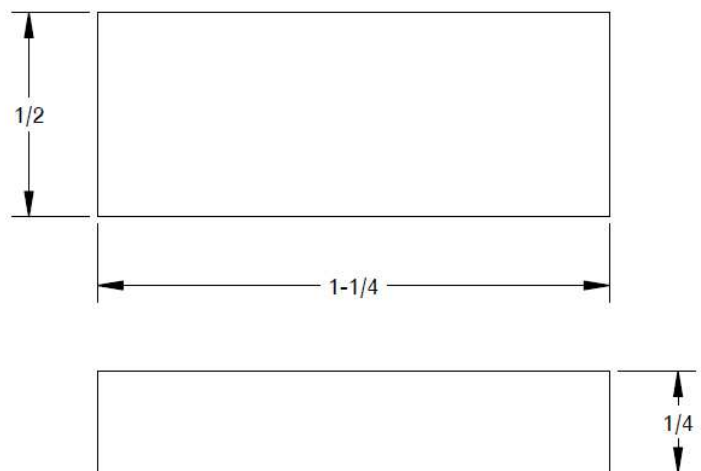


That's it, you have finished construction of the throwing arm!

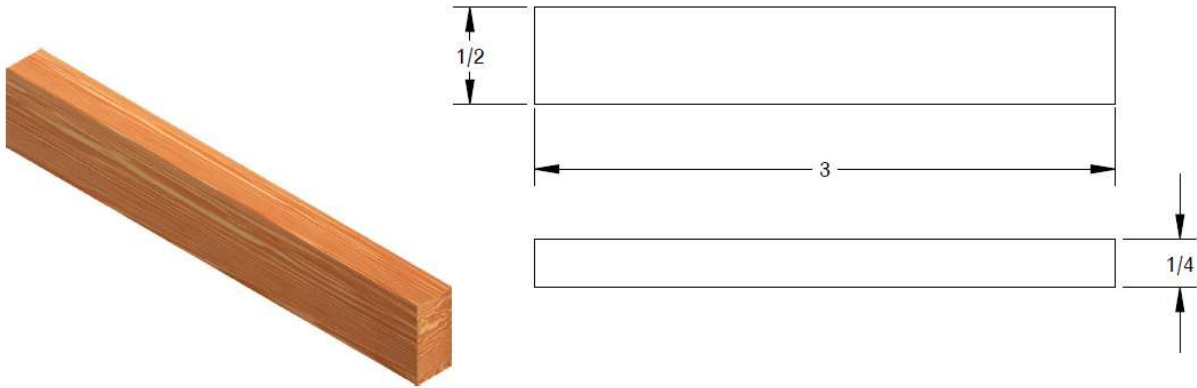
COUNTERWEIGHT BOX

Now to construct the most complicated part of this miniature trebuchet: the counterweight box. This part just has a bunch of parts making it up. Cut all the parts indicated below (again, quantities indicated in parentheses) from 1/2" x 1/4" stock.

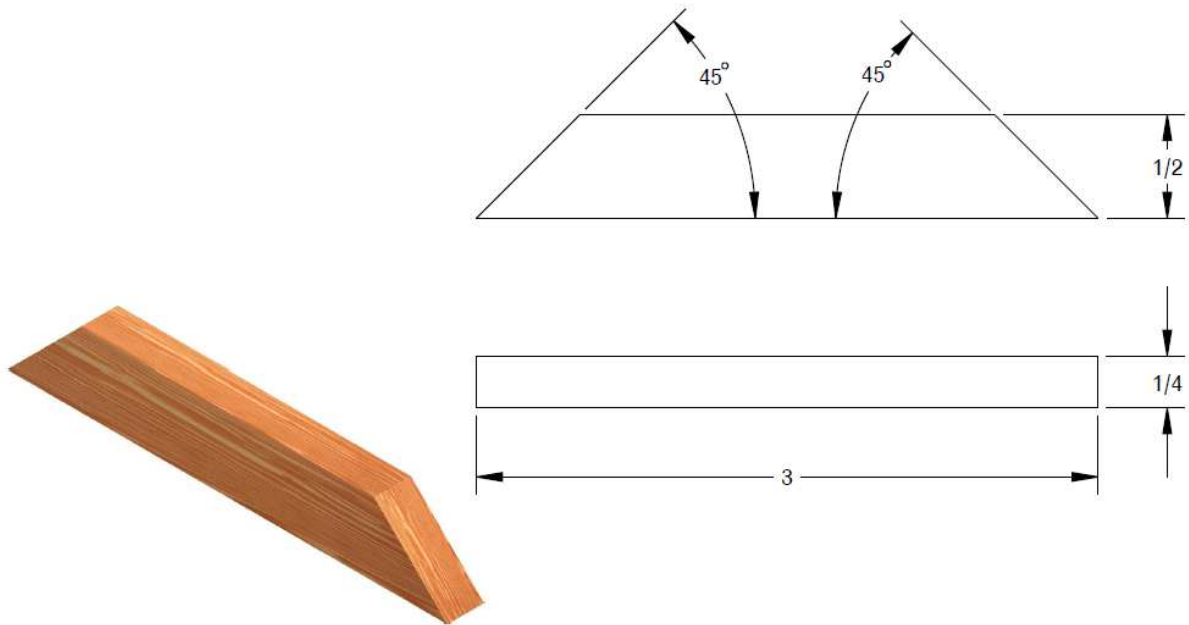
Box Bottom Piece (x6)



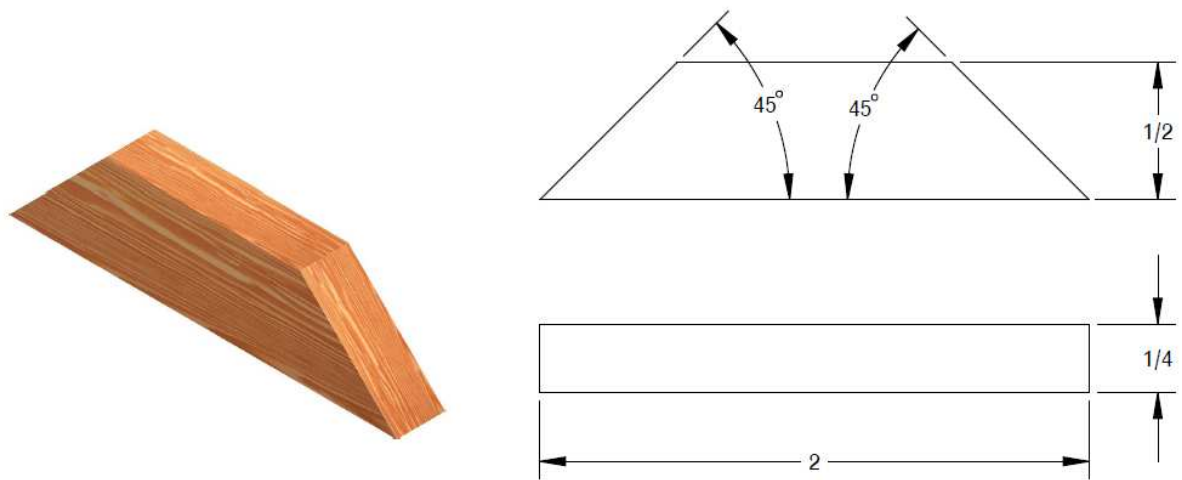
Box Side Piece 1 (x6)



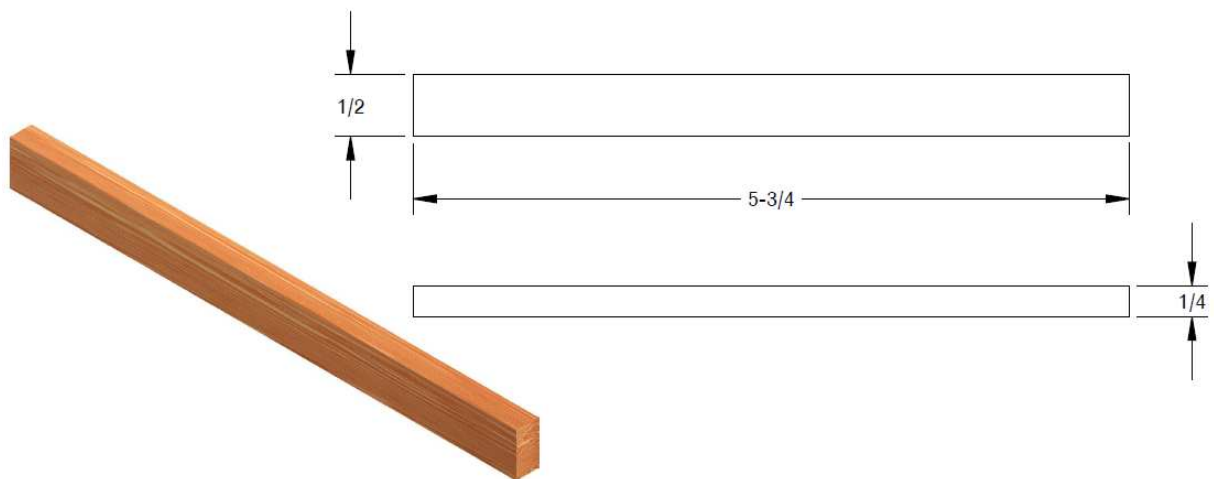
Box Side Piece 2 (x2)



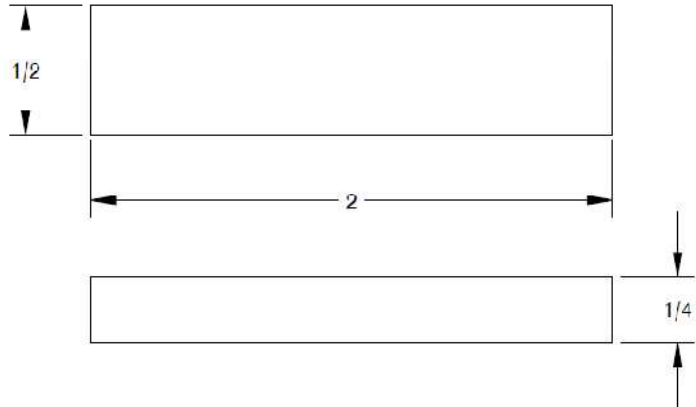
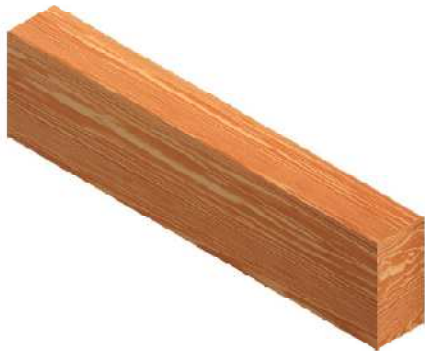
Box Side Piece 3 (x2)



Hanger Arm (x2)

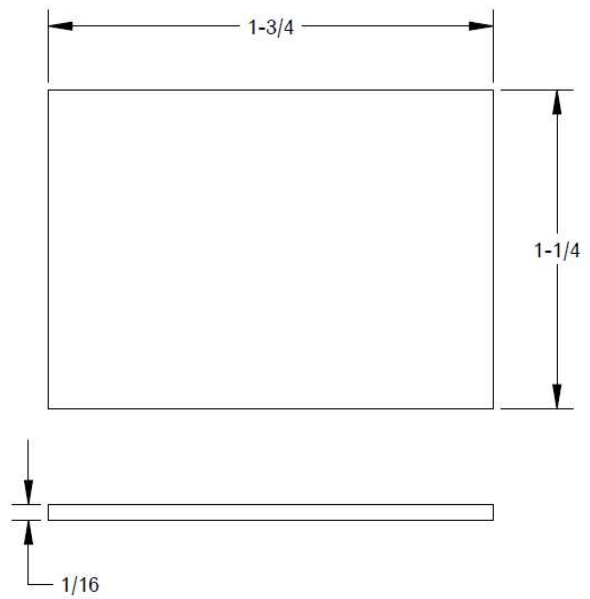


Hanger Arm Support (x2)

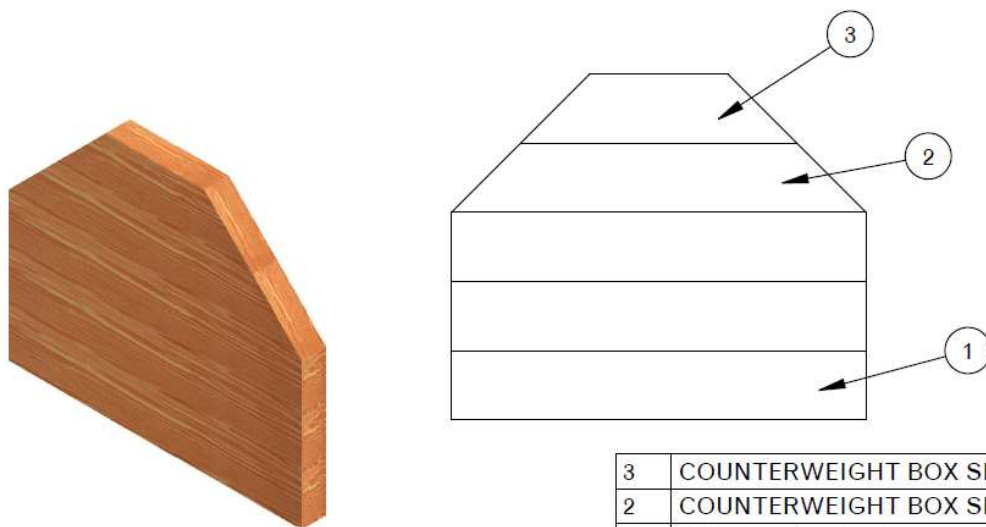


Also, cut out the following piece from $\frac{1}{16}$ " thick balsa.

Box End (x2)

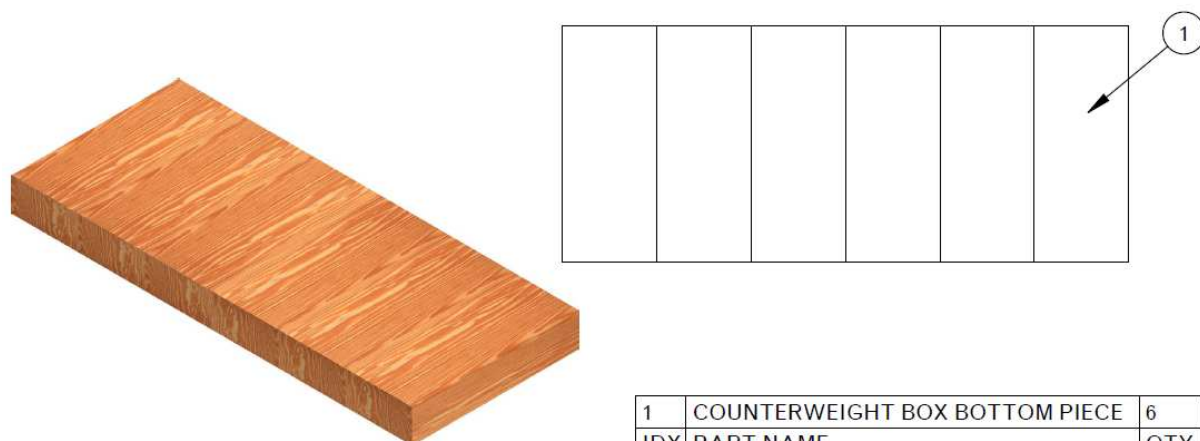


Assemble two of the following panels using the Box Side Pieces 1-3. Glue all edges together.



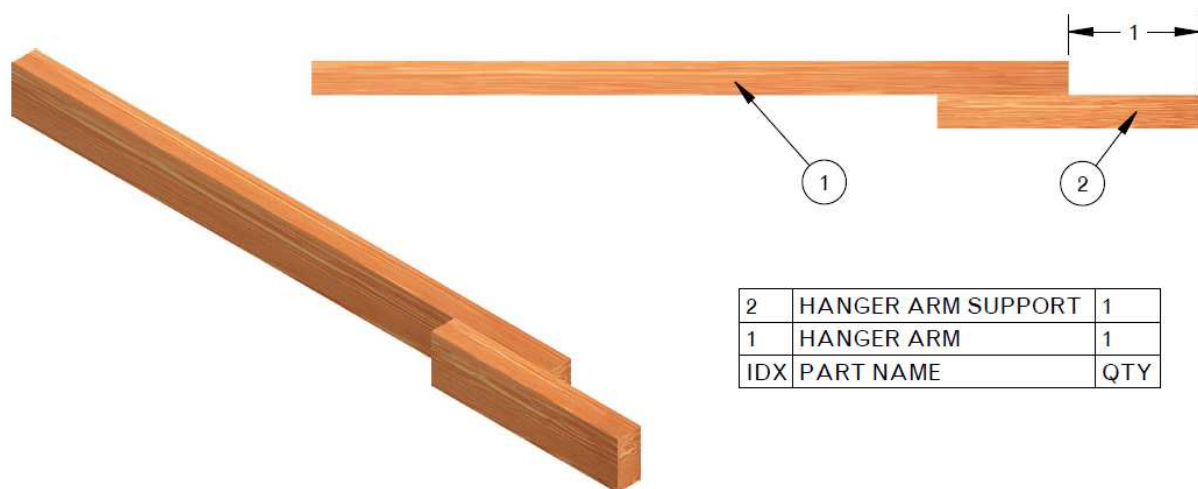
3	COUNTERWEIGHT BOX SIDE PIECE 3	1
2	COUNTERWEIGHT BOX SIDE PIECE 2	1
1	COUNTERWEIGHT BOX SIDE PIECE 1	3
IDX	PART NAME	QTY

Assemble the bottom in the same manner, shown below.

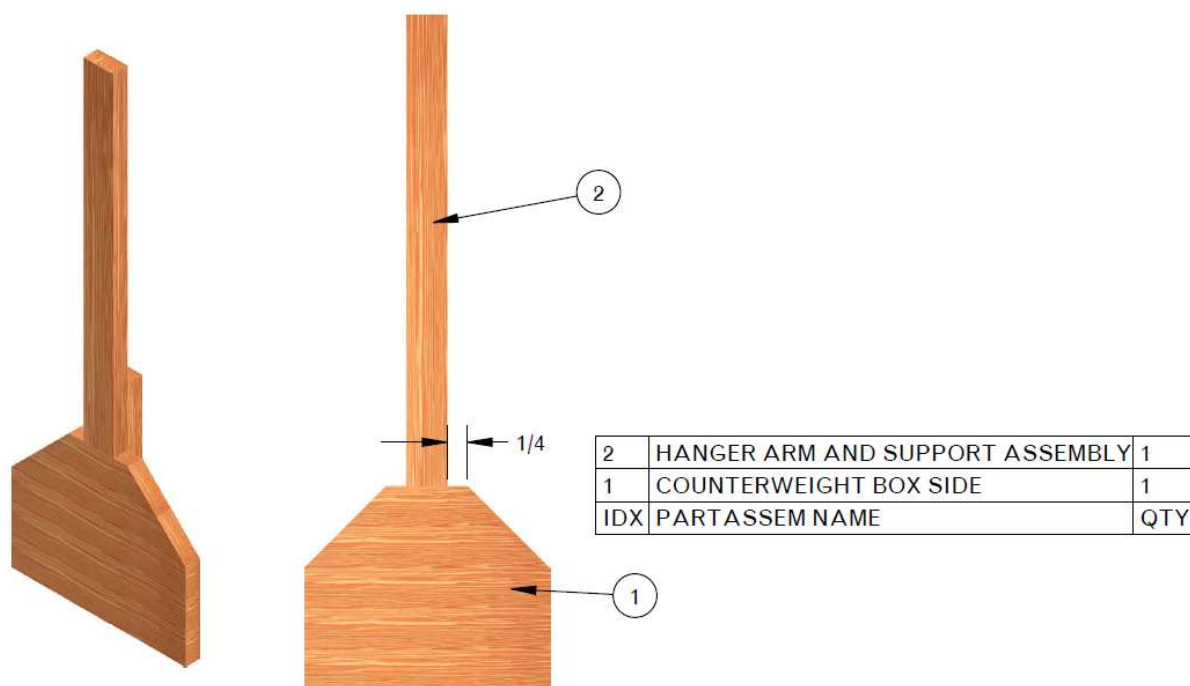


1	COUNTERWEIGHT BOX BOTTOM PIECE	6
IDX	PART NAME	QTY

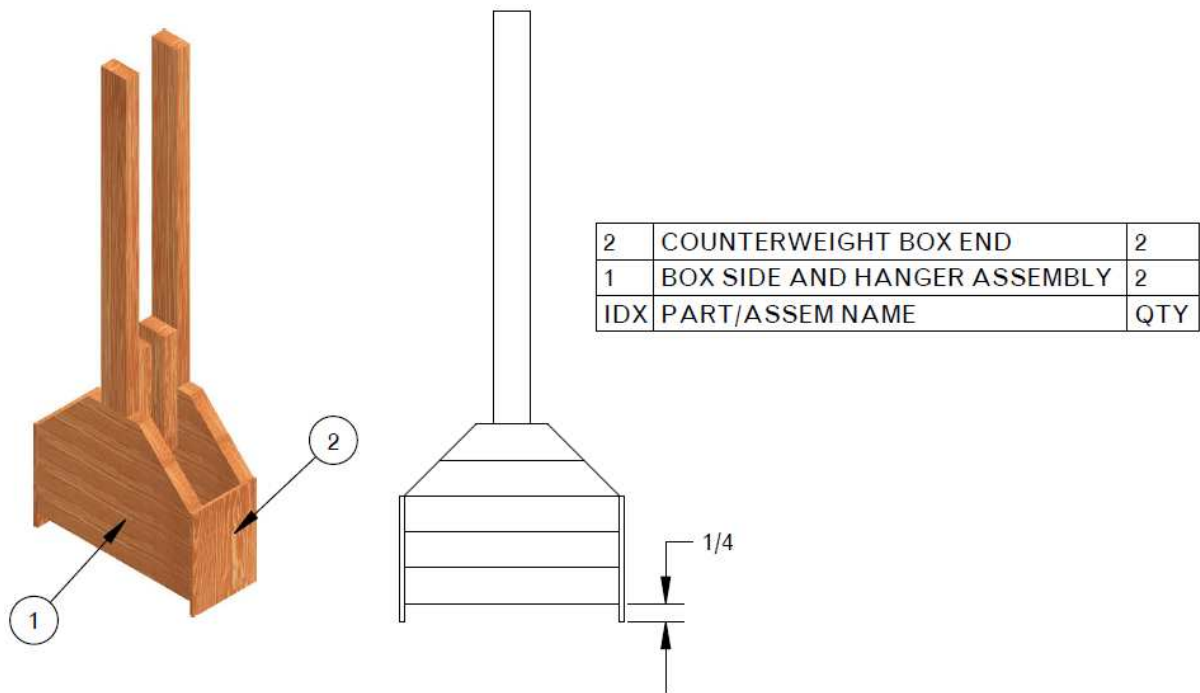
Assemble each Hanger Arm to a Hanger Arm Support as shown below.



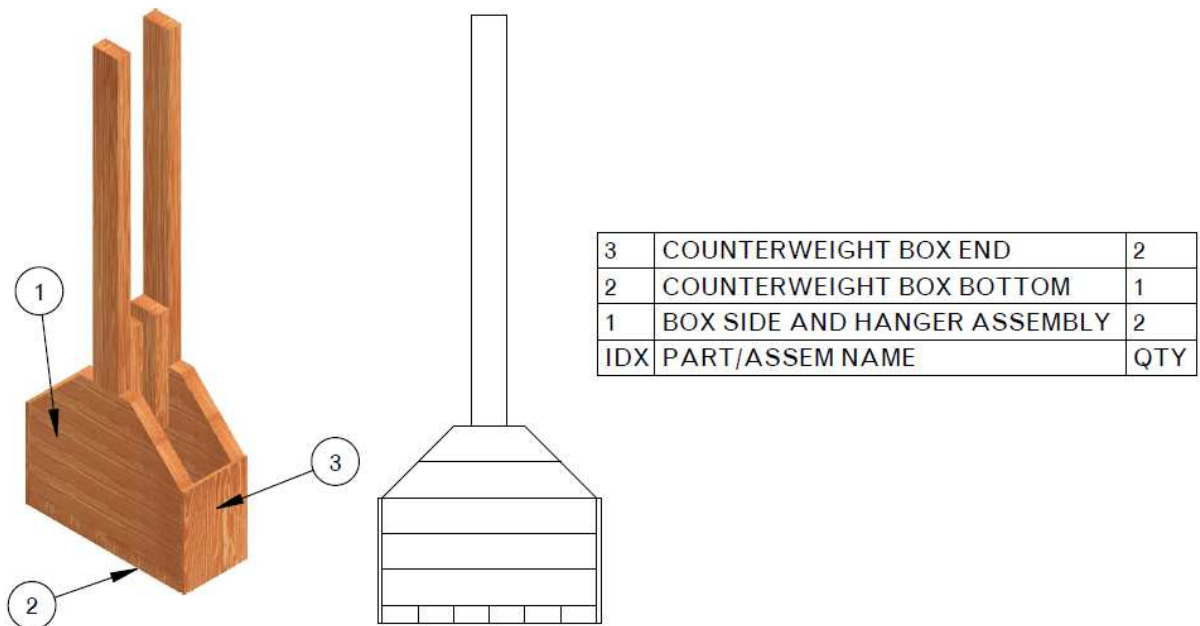
Then assemble these assemblies to the side assemblies from before.



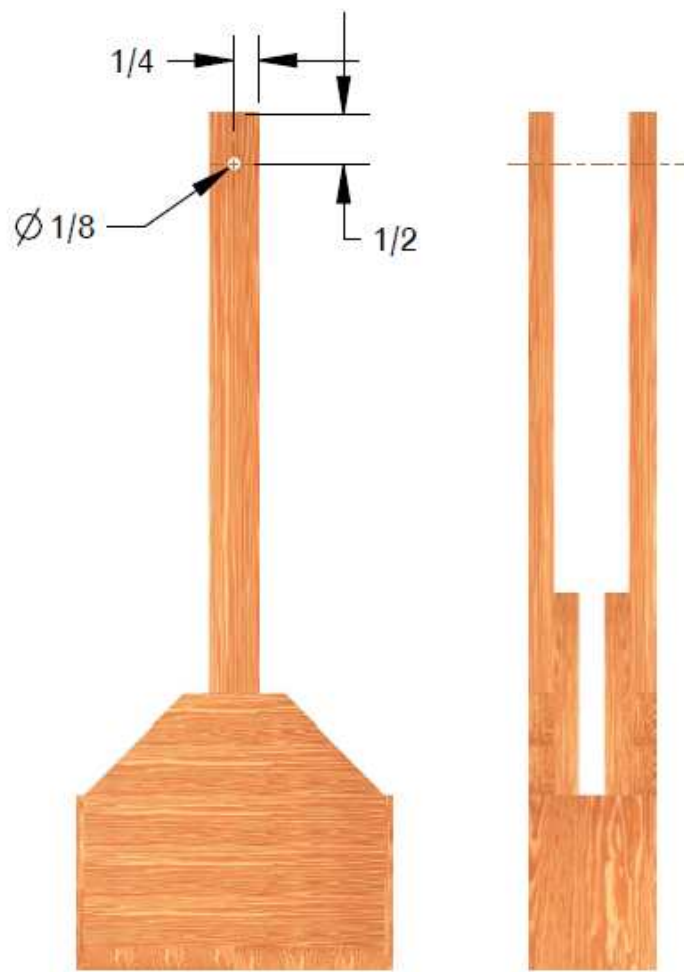
Now assemble the ends to the sides, as shown.



To this assembly, attach the bottom.



Clamp a 3/4" long spacer in between the tops of the hanger arm as shown (just like with the frame previously). Then drill a 1/8" hole as indicated through both hanger arms. It can be a tight fit or a loose fit on the 1/8" rod, just not too loose of a fit.

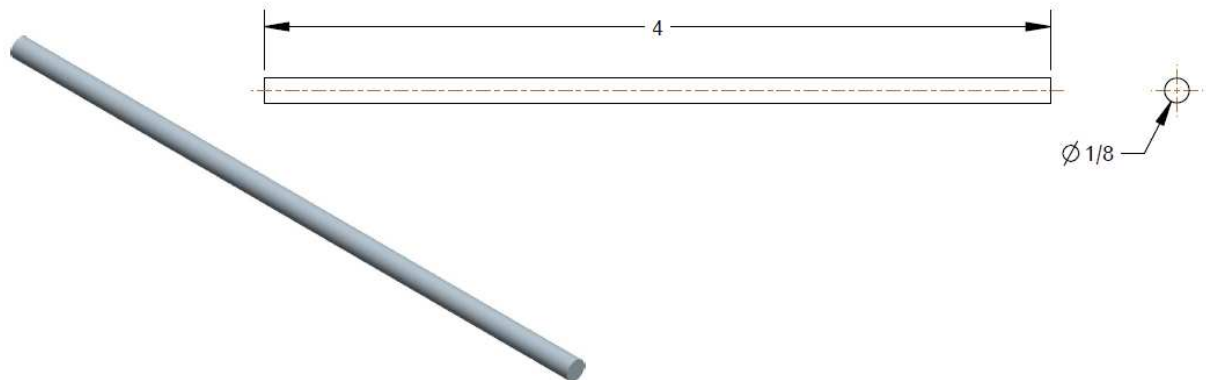


You now have a completed counterweight box!

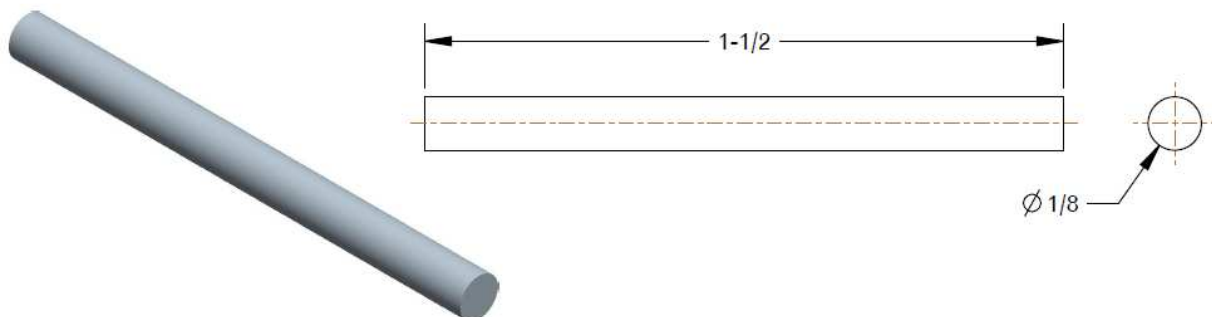
AXLES

Cut the following two pieces from 1/8" rod.

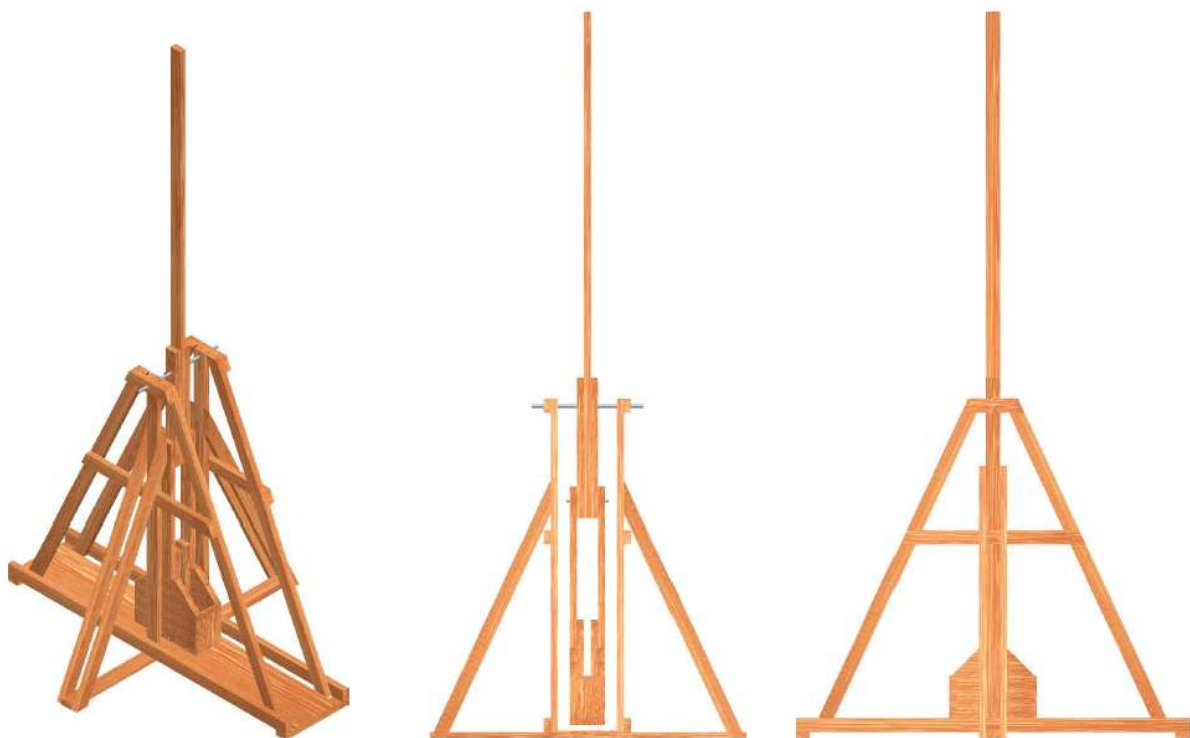
Main Axle (x1)



Hanger Axle (x1)

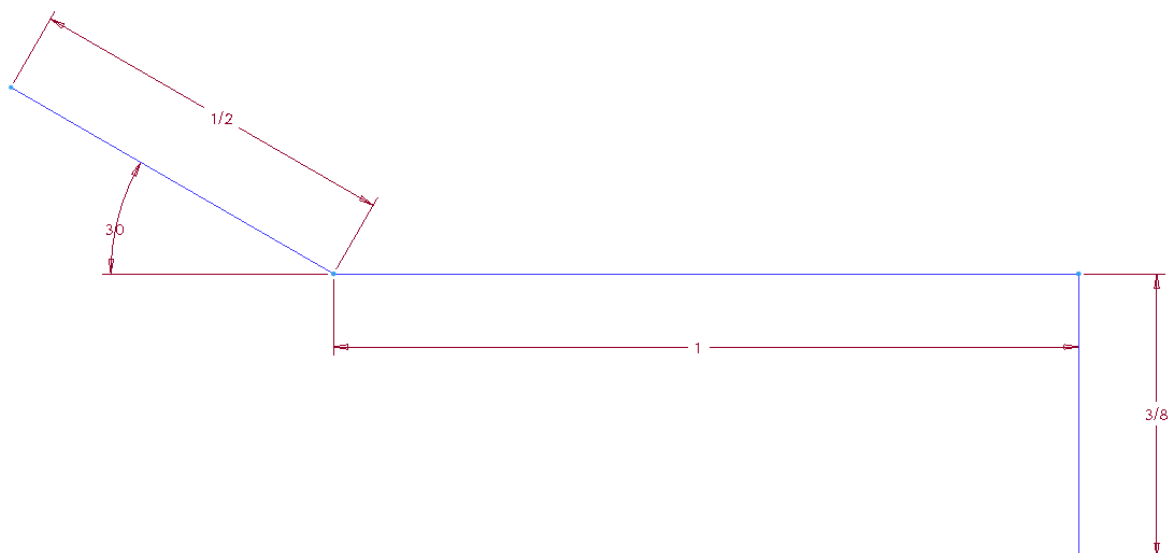


You can now assemble the throwing arm and counterweight box to the frame. The Main Axle passes through the holes in the frame caps and the central hole in the throwing arm, while the hanger axle passes through the hole in the end of the throwing arm and the holes in the hanger arms. You should now have the following:



RELEASE PIN

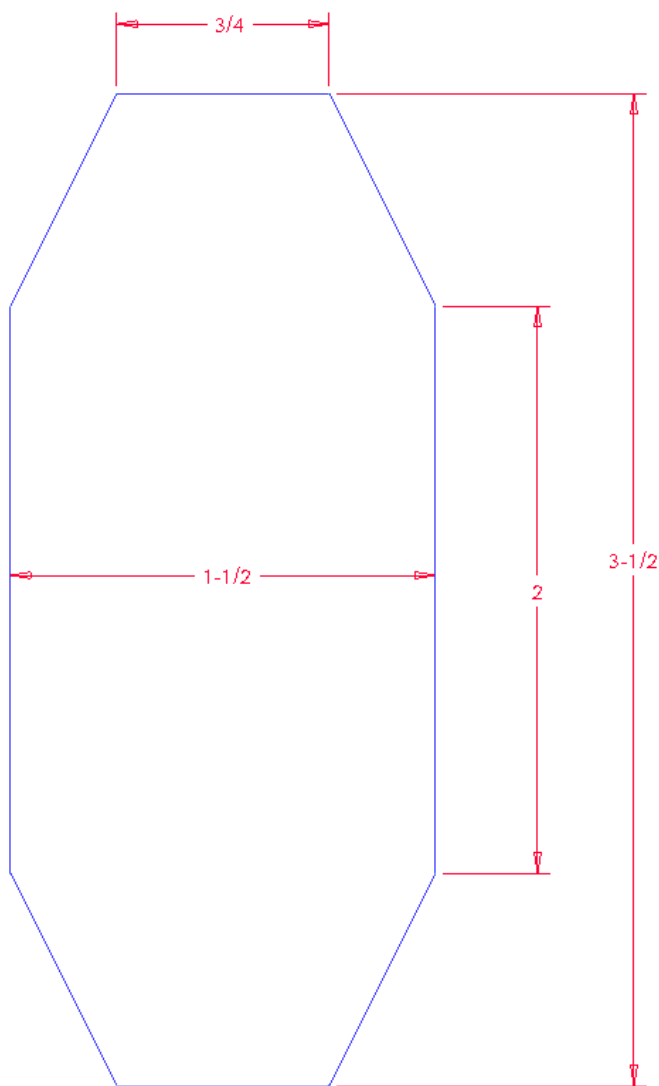
Bend a paper clip into the rough shape shown below (shape is in blue).



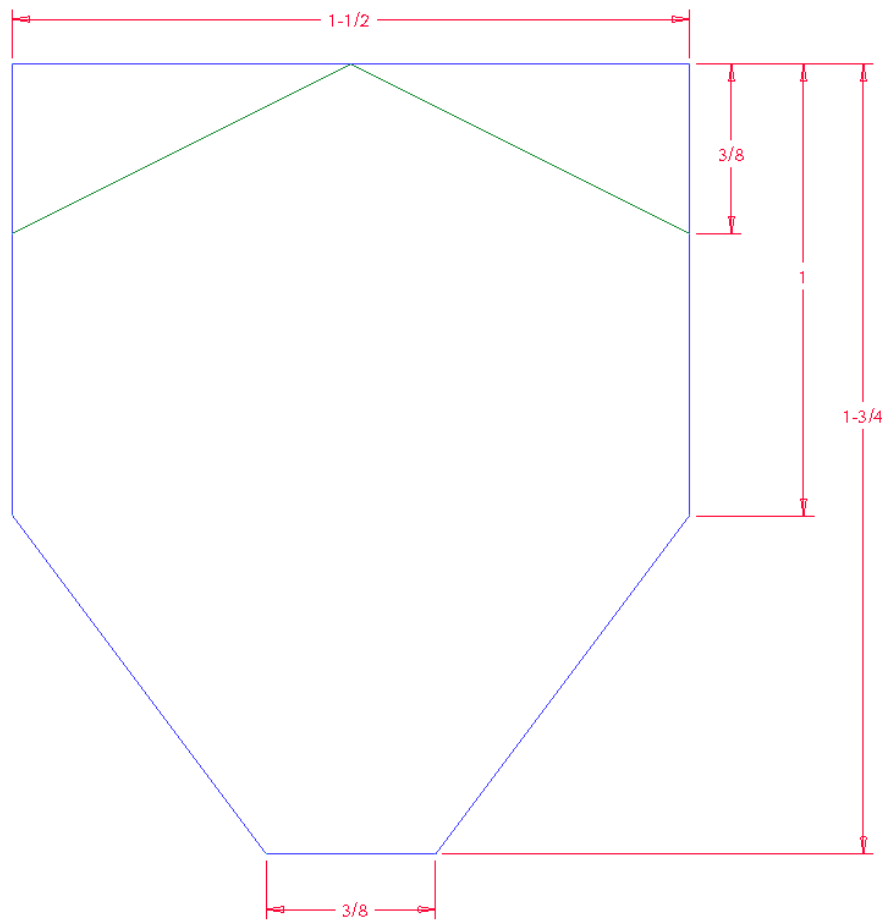
The right-angle bend should be placed into the 1/16" hole drilled into the throwing arm, and a little tape wrapped around the tip of the throwing arm and the paper clip will hold it side-to-side. This is your release pin.

SLING/POUCH

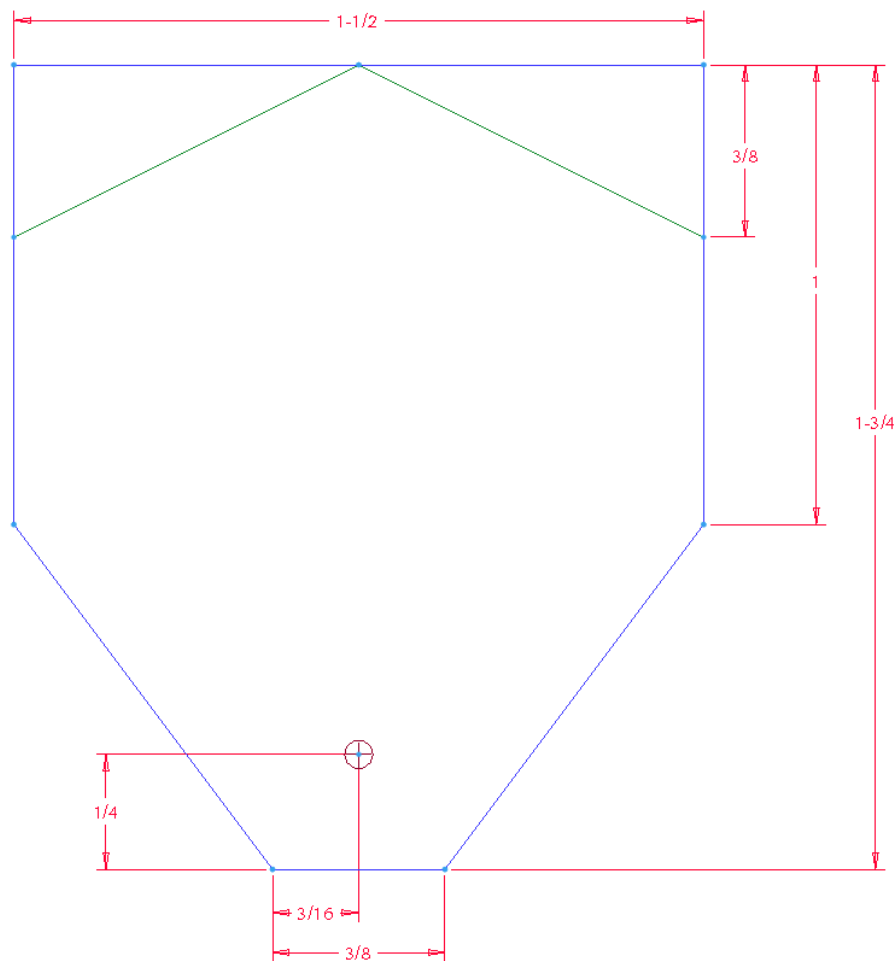
Cut a pouch from scrap of tough fabric (denim or an upholstery fabric works well) as shown below.



Fold it in half and sew/staple along the lines indicated in green below.



Punch two small holes near the ends of the pouch as shown in the red outline, these holes will be what the sling lines attach to.

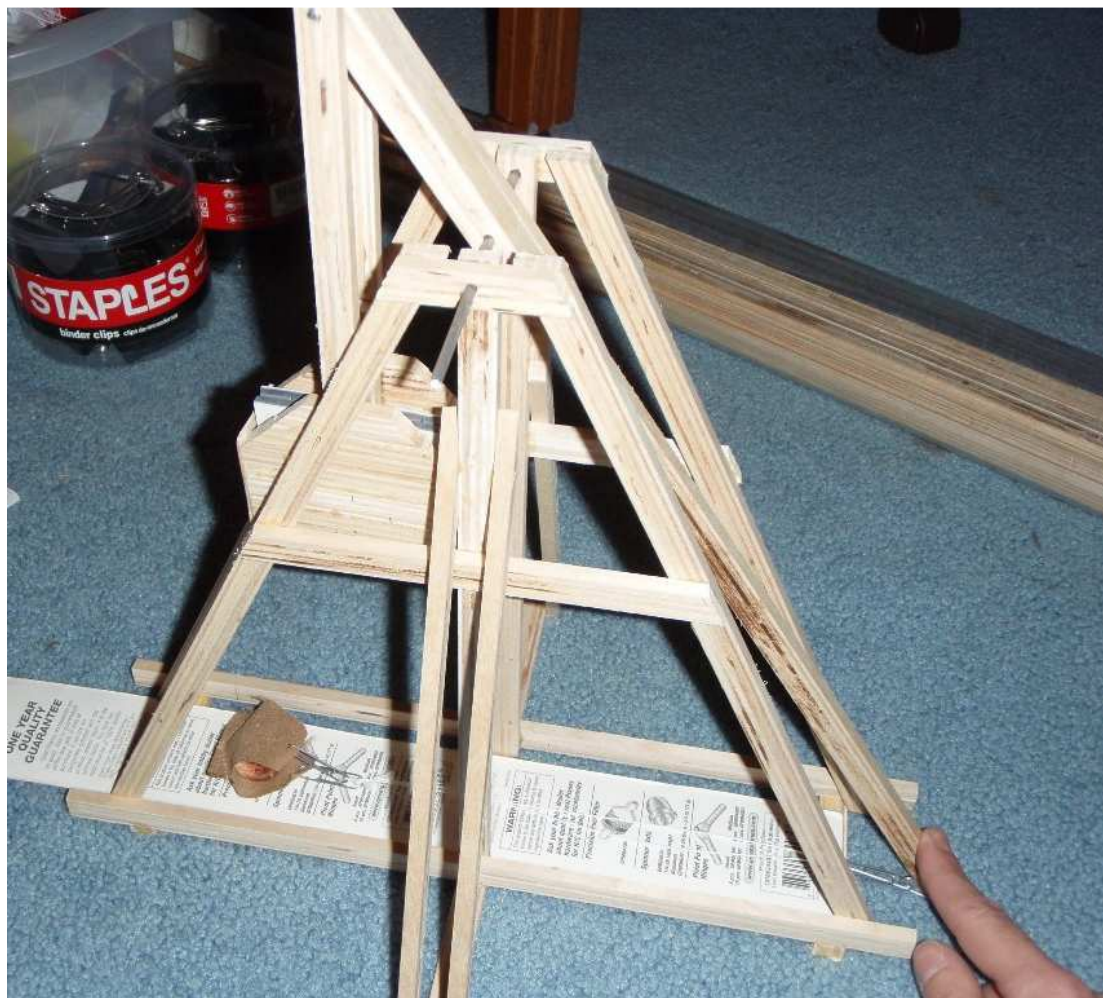


Cut two pieces of light string, one roughly 11" long, the other roughly 12" long. Tie a small loop in the end of the 12" line, just large enough to smoothly slip on and off of the release pin (paper clip). Tie the other end to one of the holes in the pouch. Take the other string, tie one end to the other hole in the pouch and the other end to the screw eye in the throwing arm.

At this point, you are ready to fire. How that works will be covered in the next section.

FIRING OPERATIONS

Operation of this trebuchet is actually pretty simple once it has been built. First, hook the loop on the loose end of the sling over the release pin (the paper clip on the end of the throwing arm). Then pull the arm tip down to the ground so that the release pin is pointed upward, not at the ground. Ensure the sling loop is still hooked over the release pin. Tuck the pouch under the arm, stretching it until the sling lines are fairly taut. Load your projectile in the center of the pouch and place it in the center of the trough (the sheet of balsa wood between the two a-frames). See the below picture for one of these trebuchets ready to fire. At this point get your face (and everything else that could get damaged!) out of the way and let it rip!



So if all went well, the projectile should have gone somewhere forward and the trebuchet should have remained intact. Should the projectile have gone backwards, check to make sure it is not rolling out of the pouch by loading it up again. If it is not coming out too early but still going backwards or basically straight up, then you can try one of two things: shorten the sling or bend the release pin more forward. Ultimately, you should get a trajectory that is roughly 40-45 degrees above the horizontal. Playing with the sling length and pin angle should get you there after some playing.

If you really want to get fancy and get the most distance you can, a video camera will be necessary, set up to the side of the machine and positioned such that you can get the whole motion of the machine plus the first couple of frames of the trajectory after launch. Then, do a couple of throws. Then shorten or lengthen the sling as needed to get the sling at roughly a 45 degree angle above horizontal when the arm stalls. The arm stall can be observed as multiple consecutive frames where the arm does not appear to rotate much. This should occur when the arm is roughly vertical. Now that the sling length has been set right, adjust your release pin angle to get the release to occur at this point with a roughly 40 degree trajectory as mentioned earlier.

Something to keep in mind: short slings swing swiftly. The meaning being that a shorter sling will get the projectile into position quicker, while a longer sling will have the opposite effect. Also, a release pin bent further forward will release later.

Potential Student/Class Project Ideas

After building the machines, a good experiment for students would be to have them find the best tuning for a certain projectile and counterweight amount. Form the students into groups and give each a different counterweight mass and projectile (try to keep the counterweight/projectile mass ratio somewhere between 75-125:1 for best results). Have them design an experimental procedure for varying the sling length and release pin angle to find the best tuning (for maximum distance).

Another idea would be to have the students chart a range of counterweight amounts, projectiles, sling lengths, and pin angles. Then as a final challenge give them a set counterweight and projectile within the range given to them to practice with. They must then use their collected data to interpolate for the sling length and pin angle to use to hit a target at a certain range. Limiting the students to a certain number of attempts with this “challenge weight” and then scoring them on how many target hits they get (or perhaps score them based on distance from target) are some of the options.