Kit Contents

Tools:

- ½” X 6” X 16” Building Board (a piece of ceiling tile)
- Risers (2),
- Rib Cutting/sanding board
- Single edge Razor blade (1)
- Tee Pins (2 sizes ea 1” & 1 ¼”
- Push Pins (6 ea)
- Emery Board (Fingernail board 1 ea)
- Crayon (wax 1ea)
- Clothes Pin Clamp 1 ea
- Plans
- CD containing plans, instructions, miscellaneous articles on rubber powered flight

Materials

- 1/16” X 1/16” X 16” Balsa (16 pcs) for rotor spars, ribs and “bump posts”
- 1/16” X 1/16” X 4” Balsa (7 pcs) for practice cutting & gluing
- 3/16” X 1/4” X 12” Balsa (2 pcs) Motor stick
- 1/8” X 1/8” X 11/16” Balsa (4 pcs) Rotor Hubs
- 1/8” X 1/8” X 1 1/4” Balsa (4 pcs) Bracing posts
- 1/8” X 1/8” X 6” Balsa (1 pcs) Spare material
- 1/16” X 1/4” X 1” Predrilled Plywood (2pcs) thrust bearing mount
- 1/32” diameter Rear Rubber Hook (2 pcs)
- Wire Rotor shaft with plastic thrust bearing (2 pcs)
- Clay ballast
- Rubber (1 pc) 1/8” X 9.5 feet

Items needed to build helicopter

- Waxed Paper (1 piece 12” X 16”)
- Glue stick
- Masking Tape
- Thread (2 pieces approximately 2 ft long)
- Glue (acetone based, white glue, wood glue or thick CA)
- Ruler or scale
- Scissors
- Patience & Practice

Items needed to fly the Helicopter well

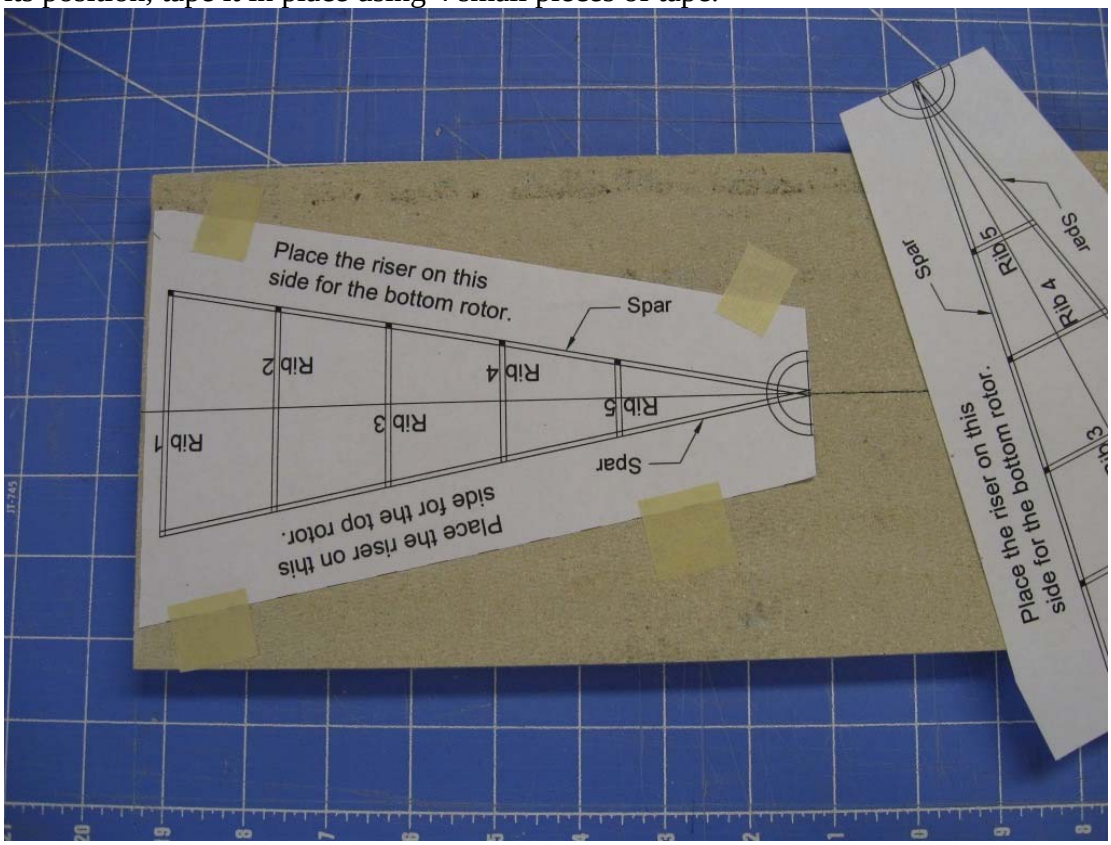
- Access to a balance that can measure 2.0 and 4.0 grams.
- Rubber Winder.
- Rubber Lube (Armor All®)
- Patience & Practice

Overview

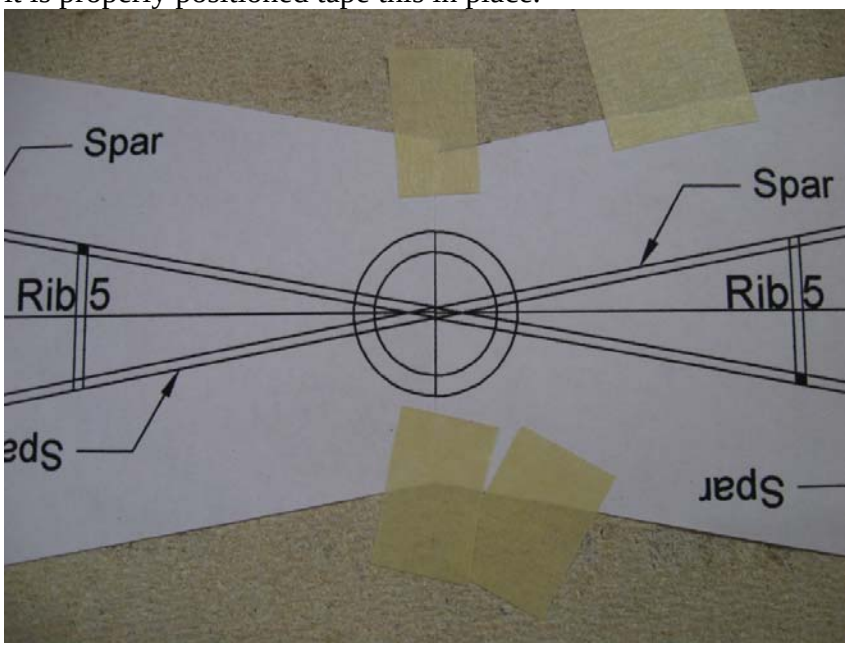
Two rotors (think propellers but Helicopters have rotors) will be built. Please note the pitch (angles of the surfaces) of the top and bottom rotors are opposite of each other. The top rotor will be at the end of the motor stick and spun by the rubber motor. The bottom rotor will be glued to the middle of the motor stick. The motor stick will have the plywood thrust bearing mount glued at one end with the rear rubber hook at the opposite

end. The motor stick will be braced with two posts and a length of thread running from each end over the posts.
PLEASE NOTE: When printing the .pdf files using Adobe you must set the “Page Scaling” to NONE or the drawings will not be full size.
Before you start please, please, please read completely through the instructions and become familiar with the images. This will prevent a lot of mistakes.

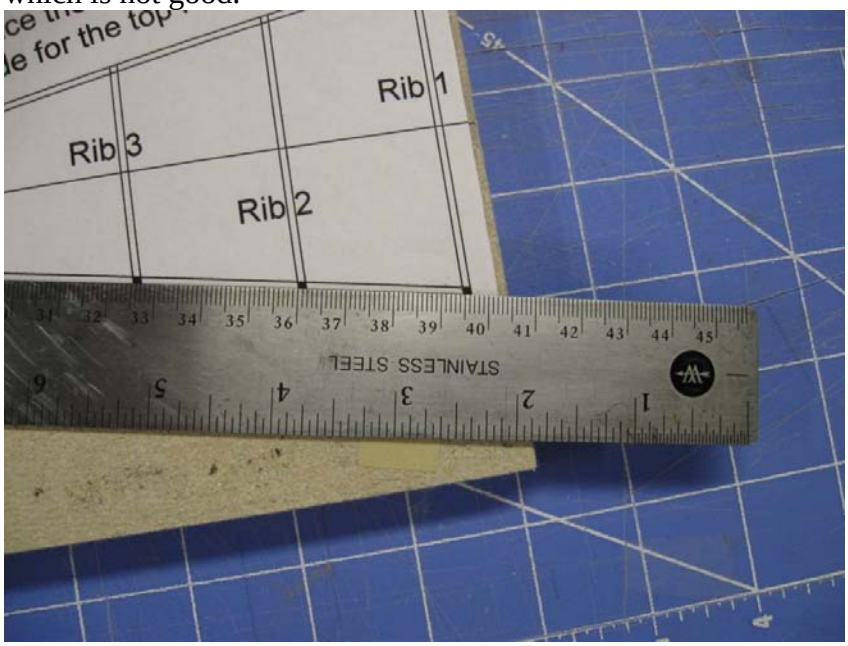
Step 1 Preparing the Building Board.
Find a flat surface where you can place the building board. A kitchen table generally works nicely.
Cut the rotor plan along the dashed lines to yield two pie shaped pieces. Place one piece on the building board with the small end near the center of the board. The center line on the plan should be directly over the line drawn on the board. Once you are satisfied with its position, tape it in place using 4 small pieces of tape.



Place the other plan on the building board aligning the circles at the small end with the circles on the other plan and the centerline on the line drawn on the building board. Once it is properly positioned tape this in place.



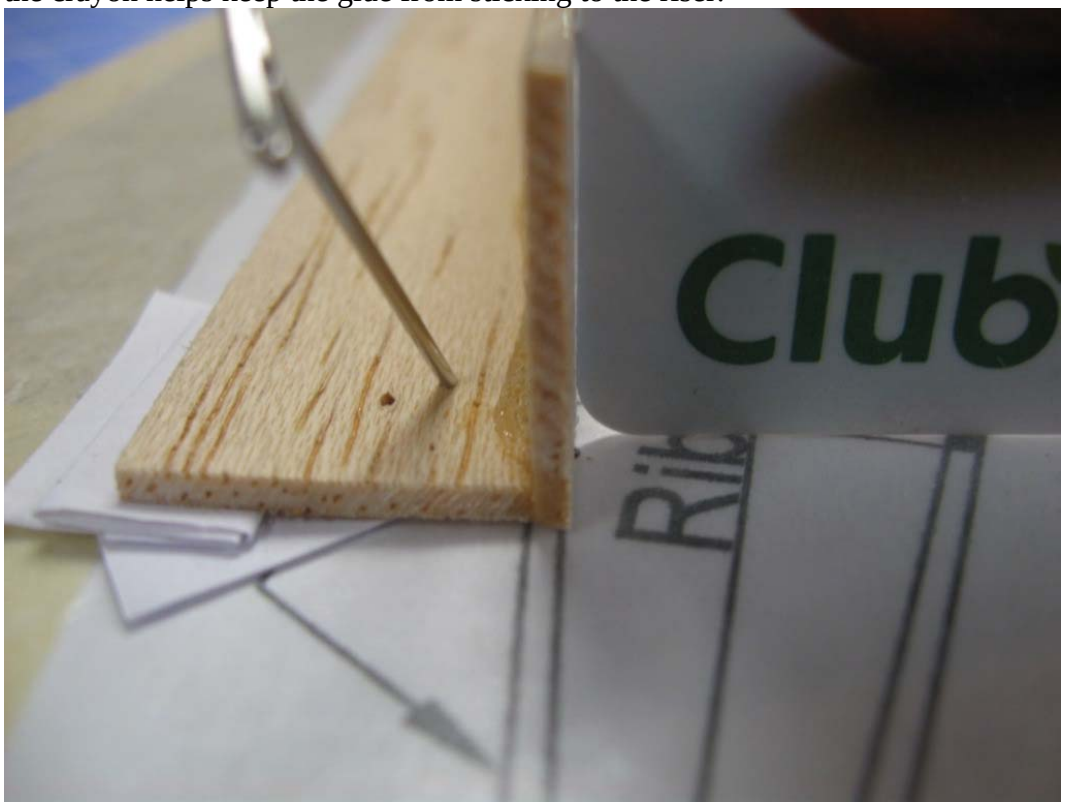
Because paper shrinks and stretches, measure the overall length of the rotor spars (not the centerline). They should be about 39.7 centimeters. Making the rotor slightly smaller than the allowable maximum is intentional. If the rotor does not turn exactly about its center, the diameter swept by the longer of the two “halves” can be greater than the 40.0 cm limit which is not good.



Cover the building board with a piece of waxed paper and tape it in place. This will prevent the parts from becoming glued to the plans and board. Both the top and bottom rotors will be built using this one plan. If need be place weights on the board to flatten it to the table. You do not want the board to be bowed.

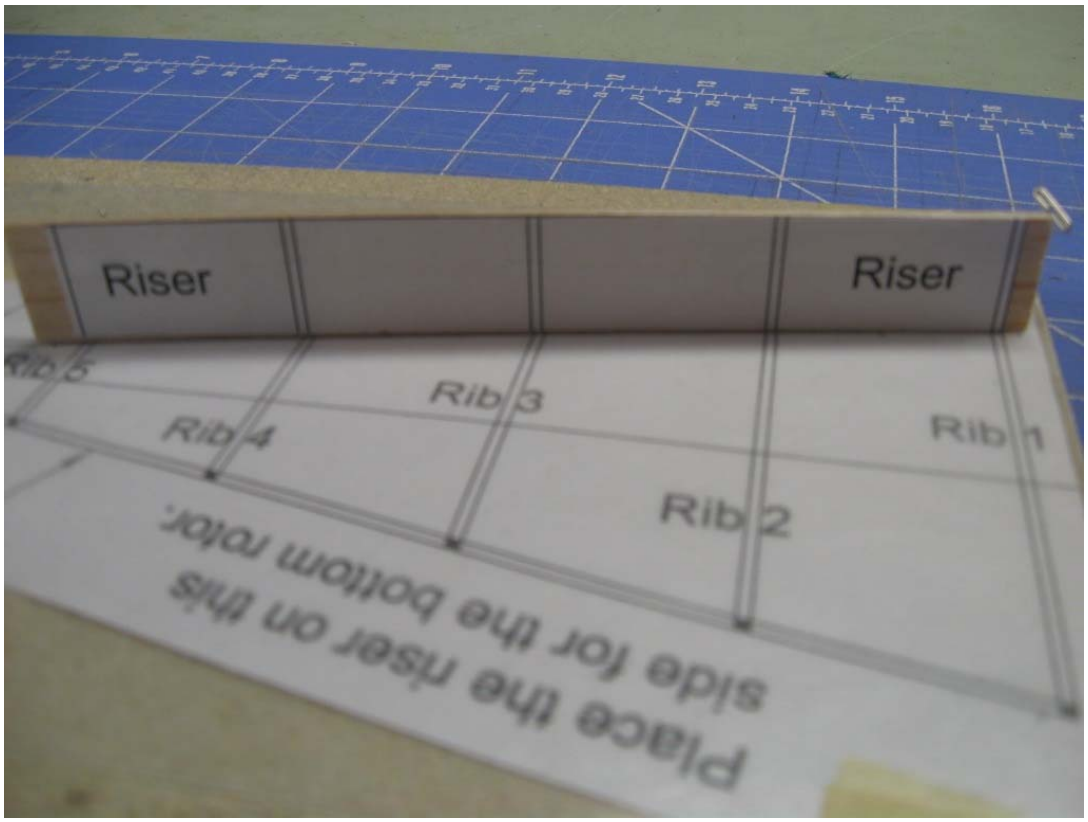
Step 2 Risers

Take one of the two risers and position it so the top surface of the vertical piece is directly over the outline of the rotor spar. The top of each riser has been covered with Scotch® brand gloss finish transparent tape to prevent glue from sticking to the riser. For added insurance you can rub the top and front edge with the supplied crayon. The wax in the crayon helps keep the glue from sticking to the riser.



In the image above a paper wedge is use to get the top surface directly over the spar outline on the plan. You can either shim the bottom leg to angle the lean the vertical leg so the top surface is directly over the spar outline or move the riser until the top surface is over the outline. It is not important to have the vertical face of the riser perpendicular to the building board.

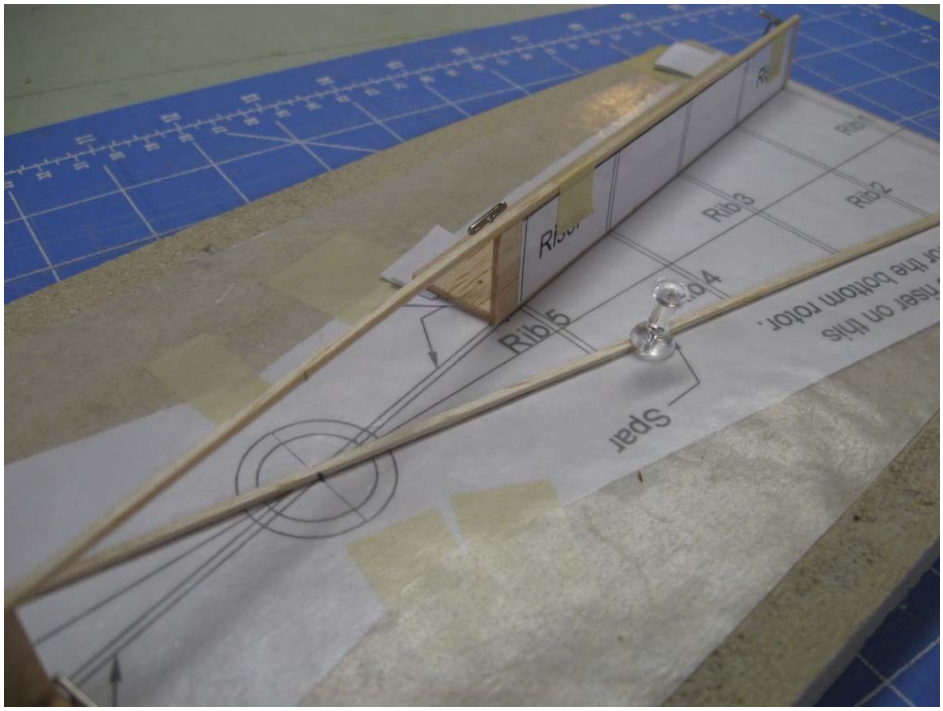
Locating the upper spar for the rotor DIRECTLY over the outline is IMPORTANT. Align the vertical double lines on the riser to the double lines identified as Rib 1 on the rotor plan. There will probably be a mismatch at Rib 5 of ½ to 1 millimeter (remember about paper shrinking and stretching?). This mismatch will not create a problem because the exact location of the ribs is not that critical.



Use the Tee pins or weights to hold the risers in place. Now place the other riser on the opposite side and opposite end of the rotor. Align this one as you did with the first. You should have covered two sets of words saying the same thing and left uncovered another two sets of words that say “Place the riser here to build the top (or bottom) rotor”. It does not matter if you build the top rotor or bottom rotor first. Just remember to build one of each!

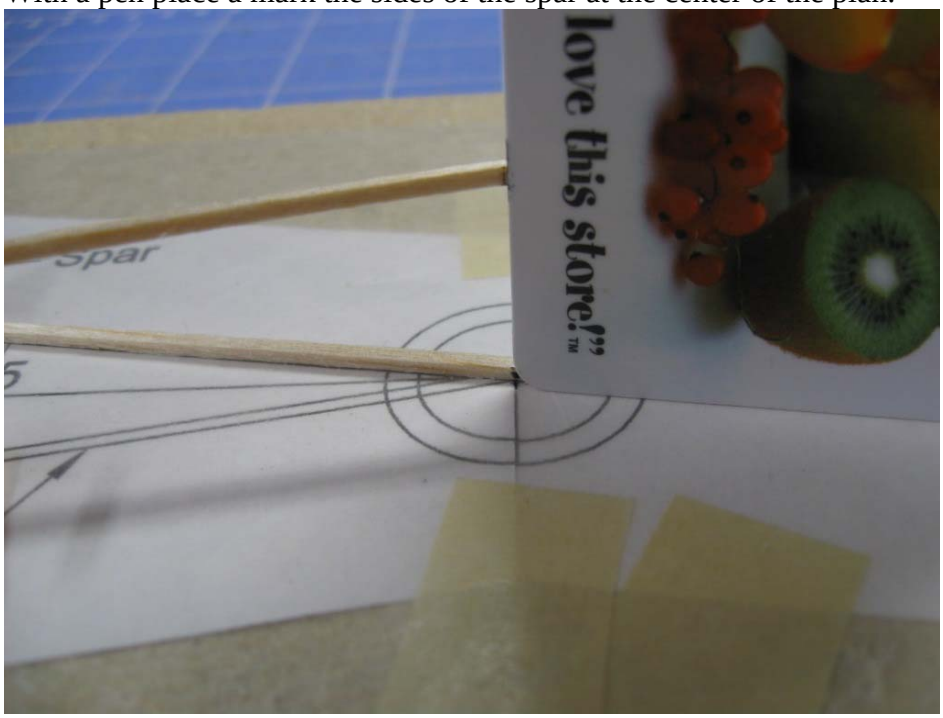
Step 3 Rotor Spars

Place a piece of 1/16” X 1/16” X 16” balsa directly on the wax paper covering the outline of the rotor spar. Align it so both ends of the spar extend past the outline on the plan. Once it is aligned, use push pins to hold it in place. You will need to use the bottom of the plastic head to hold the balsa stationary. The pins should not be located where the outlines of the ribs join the spars. Allow room to glue the ribs on the top surface of this spar.



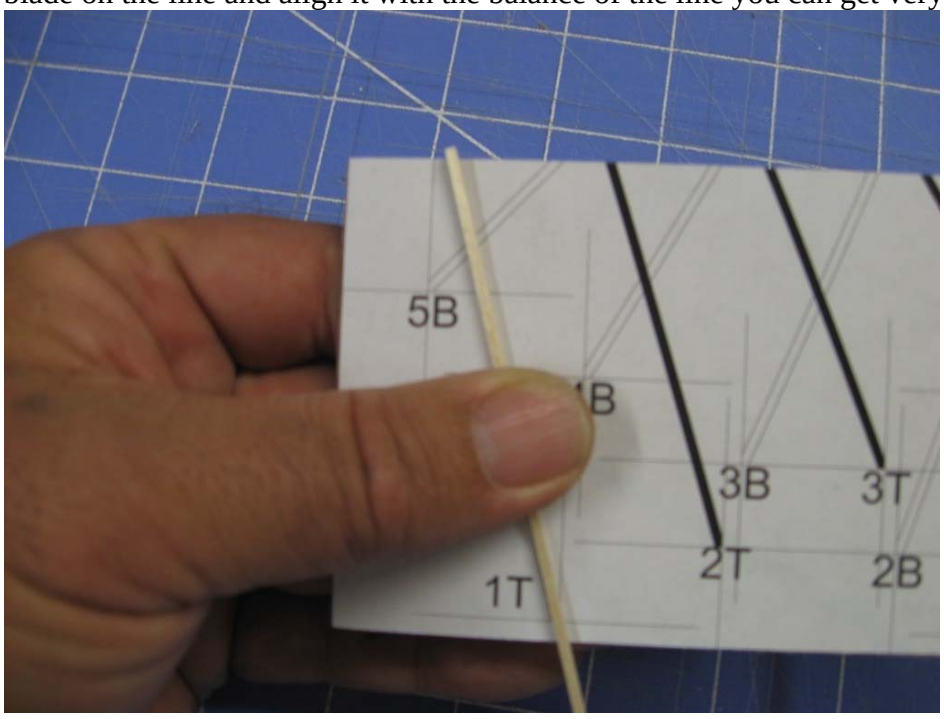
A gentle touch is needed when installing the pins. Do not apply so much pressure that you crush the wood and never push the pin through the balsa. Have 4 pieces of masking tape about ½” X ¾” ready. Place a piece of 1/16” X 1/16” X 16” balsa on the top of the risers. Again, both ends of the spar need to extend past the ends of the risers. Attach the spar onto the riser using two pieces of tape on each riser. Do not put tape where the ribs will be glued. Do not trim the ends of the spars. We will do that later.

With a pen place a mark the sides of the spar at the center of the plan.



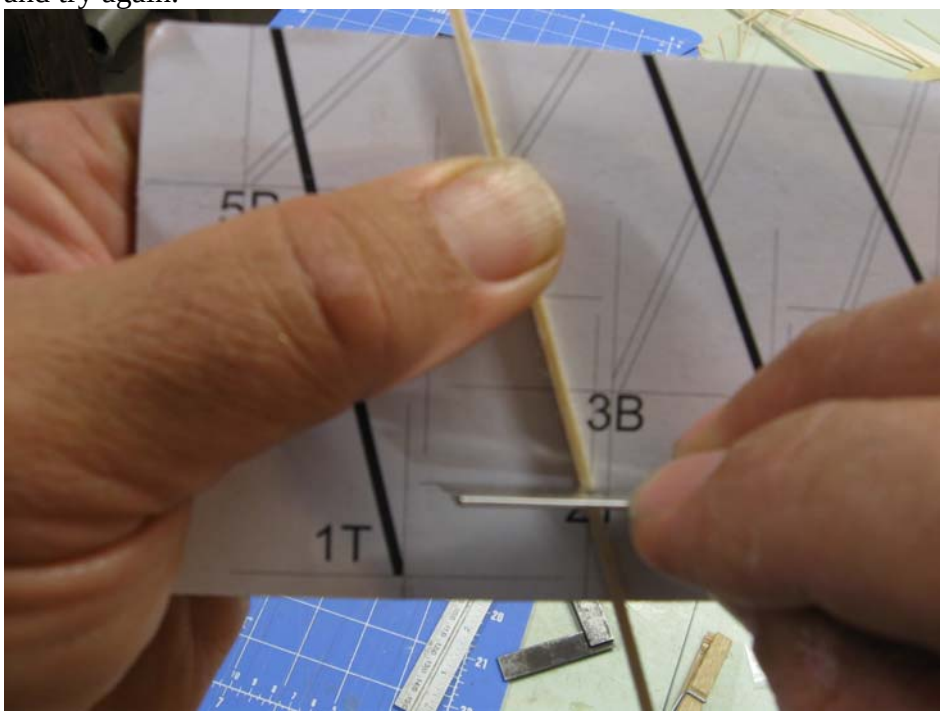
Step 4 Cutting & Sanding Ribs.

This step might take a bit of practice before you get the results you want so be patient.
It is important to say a few words about cutting balsa.
First: Supplied in the kit is a single edge razor blade. Razor blades are very SHARP. Handle them carefully and only by the reinforced edge where the metal is folded over.
Second: Even though the razor is sharp you must slice the wood not try to chop it. As you apply downward pressure on the razor blade, push or pull it forward or backward to slice the wood. If you just push down with the razor blade, to cut the wood you might get a good cut once in a while but most of the time the wood will crush.
Third: This is hard to do consistently; hold the razor perpendicular to the cutting surface. You want the razor cuts to be vertical to get achieve strong glue joints. This means the cut face of the rib must fully contact the surface of the spar.
Use some of the short pieces to practice with.
Now let's look at the Rib Cutting/Sanding Board.
At first this is confusing with all of the lines, letters and numbers.
The wide (1/16") solid lines are the ribs for the top rotor. You will need two of each rib; one for each blade of the rotor. They are marked 1T for Rib 1 Top Rotor, 2T for Rib 2 Top Rotor and so on. The ends near the numbers and letters will be glued to the bottom spar. You will see each of these ends have a pair of perpendicular lines attached to a corner. These lines are guides for the razor blade. If you place one corner of the razor blade on the line and align it with the balance of the line you can get very accurate cuts.

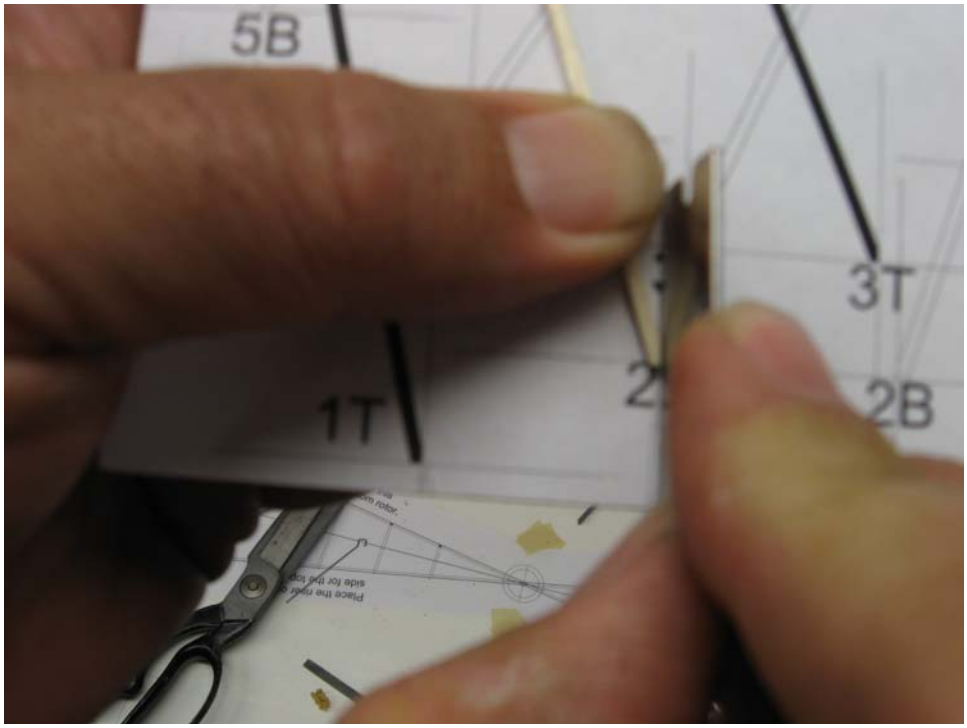


Where all the ribs stop at the edge of the board, are the ends that will attach to the upper spar (the one taped on the riser). These ends will be glued to the vertical face of the spar and will need a compound angle. While there are a number of ways to cut the ribs, I have a method to recommend. Place the 1/16" X 1/16" square balsa over the outline of the longest rib leaving a little (1/32" – 1/16") extended over the edge of the board.

Cut the rib to length using the lines parallel to the long edge. This cut is not critical since this face is not glued to anything. If the cut is bad, move the wood to the next smaller rib and try again.

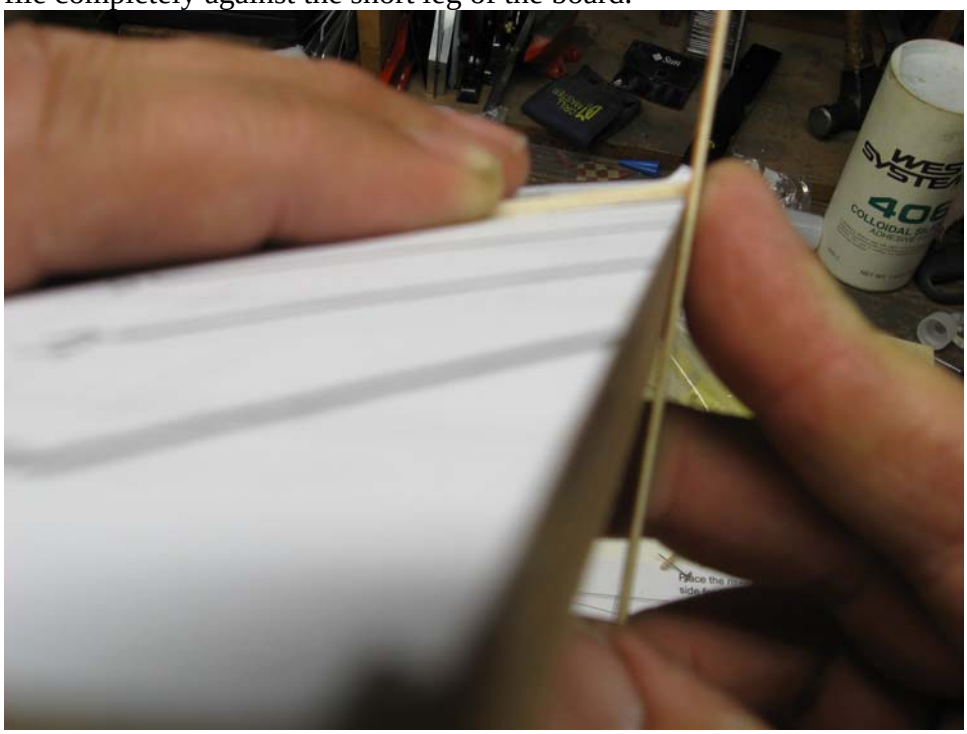


Once this cut is made, make the second cut using the guide line that is perpendicular to the first cut.



While still holding the rib in place, exchange the razor blade for the nail file and sand the compound angle on the opposite end. Be sure not to tip or lean the nail file over the board

as this will ruin one of the angles. The last passes of the nail file should have the face of file completely against the short leg of the board.

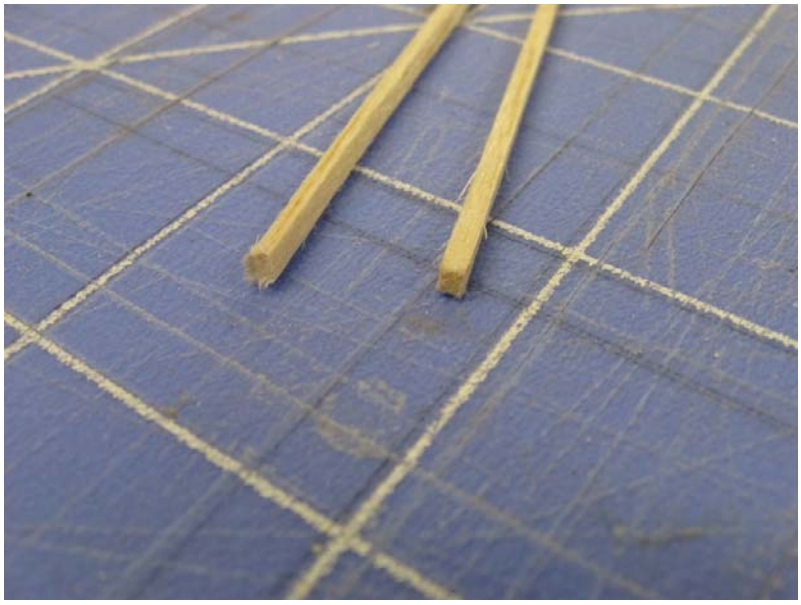


Instead of using the nail file you can try to lay the razor against the short leg of the board and slice the end of the rib. If this method does not work for your try other sequences until you find one that does and stick with it to gain proficiency.

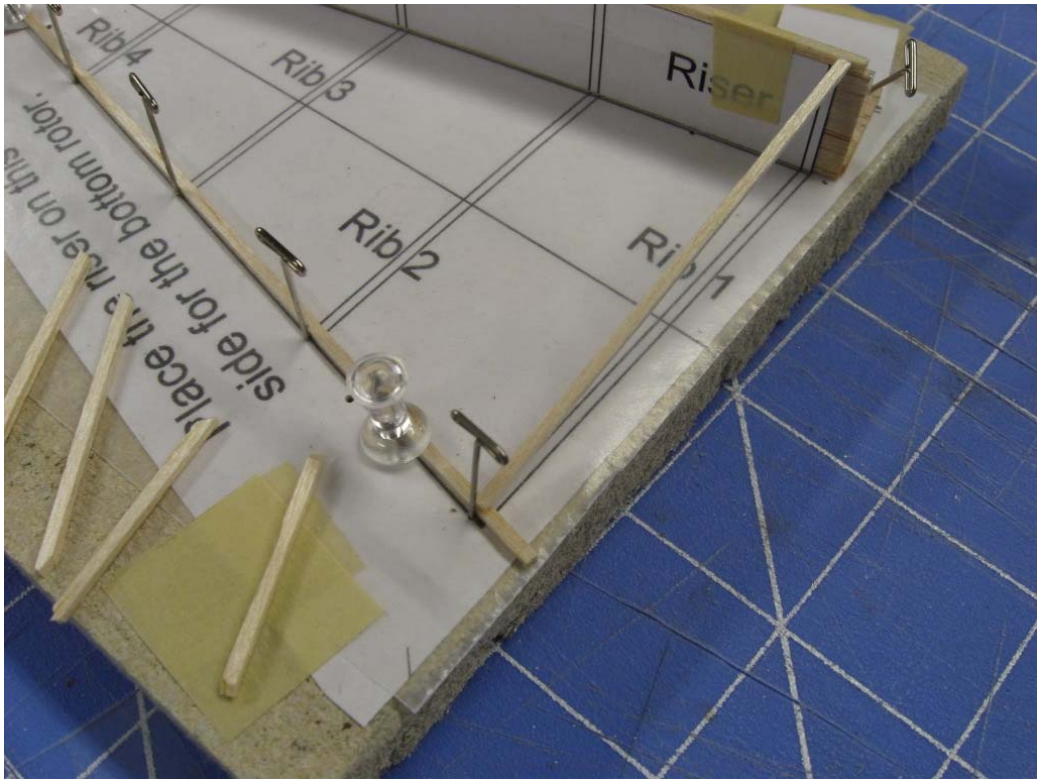
I prefer to cut one set of ribs and glue them into place as opposed to gluing each rib as they are cut. The choice is yours. Just remember to make two of each number/letter. The solid marks are for a top rotor ribs and the outlined marks are for the bottom rotor ribs. Place marks (magic marker, felt tip pen) on the spars and/or ribs so you will be able to easily identify the top rotor from the bottom rotor and the top side of each rotor. Once they are removed from the building board it is easy to confuse them.

Step 5 Gluing the Ribs to the Spars

If the risers and spars are placed perfectly AND the ribs are cut and sanded perfectly AND I sliced the spars to exactly the right width, then everything will go together just right……this will not happen. Be prepared some ribs to be a bit too long or some too short. This is not the end of the world. I recommend placing one of the short (1”) Tee pins on the outside of the spar that is pinned to the building where the rib will be glued. Before applying any glue test fit the rib by placing one end against the pin and the other against the spar taped on the riser. WOW! With all that fuzz on the sanded end it is hard to tell where the rib ends and the hair begins. Just take the nail file and VERY LIGHTLY wipe the fuzz off of the edges. The pressure needed is so little that the weight of the nail file itself is enough to remove the fuzz.

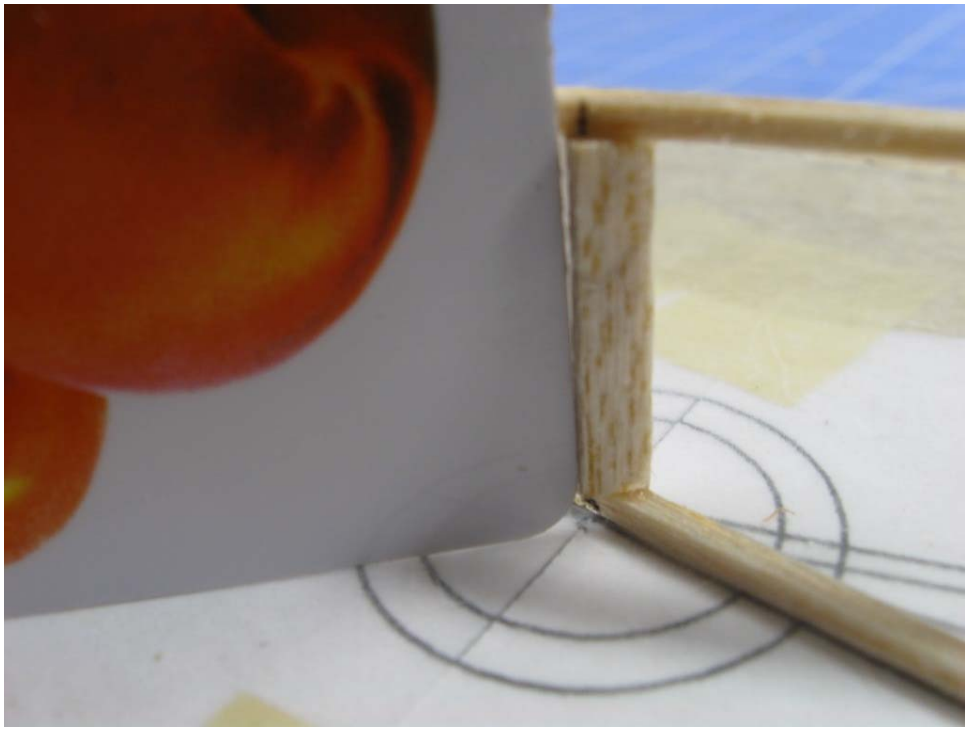


Note the “fuzz” or balsa hair on the piece on the left.
Now with that behind you let’s check the length and fit of the rib. If the rib is too short move it toward the center of the rotor, if too long move away from the center. If you have to move the rib more than its thickness (completely outside of the double lines) it should be either trimmed (too long) or make a new one (too short). Do not move Rib 1 away from the center or the rotor will exceed the 40.0 cm diameter.



This image shows an excellent fit at the joint between the upper spar and rib. Do not be upset if this is not the case for all of the joints.

Apply a small amount of glue to the end of the rib that will be attached to the lower spar (the one pinned to the Building Board). Place the rib on the spar and slide it against the 1” Tee pin. Just rest the other end of the rib against the upper spar and let the joint dry. Continue gluing the remaining 9 ribs in this manner. Once the glue has dried raise the unglued end of a rib away from the spar to create a space about 1/8”. Apply a small amount of glue to the rib and gently push it back into contact with the spar. Do this for the remaining 9 ribs and allow the glue to dry. Once the glue is dry, use a piece of 1/16”X1/16” Balsa and gently push against each ribs’ glue joints. If any are loose, glue the joint again. The ribs must be firmly attached to the spars or the rotor will disassemble while spinning and ruin your day.
Take the 1/8” X 1/8” X 11/16” Balsa Rotor Hub and glue it between the upper spar (taped to the riser) and the lower spar (the one pinned to the building board) exactly in the center of the rotor. The marks you made earlier on the sides of the lower spar will help locate the center of the rotor. Use something square (a credit or ID card will work) to make sure the Rotor Hub is vertical. Each end should be in the center of the rotor.

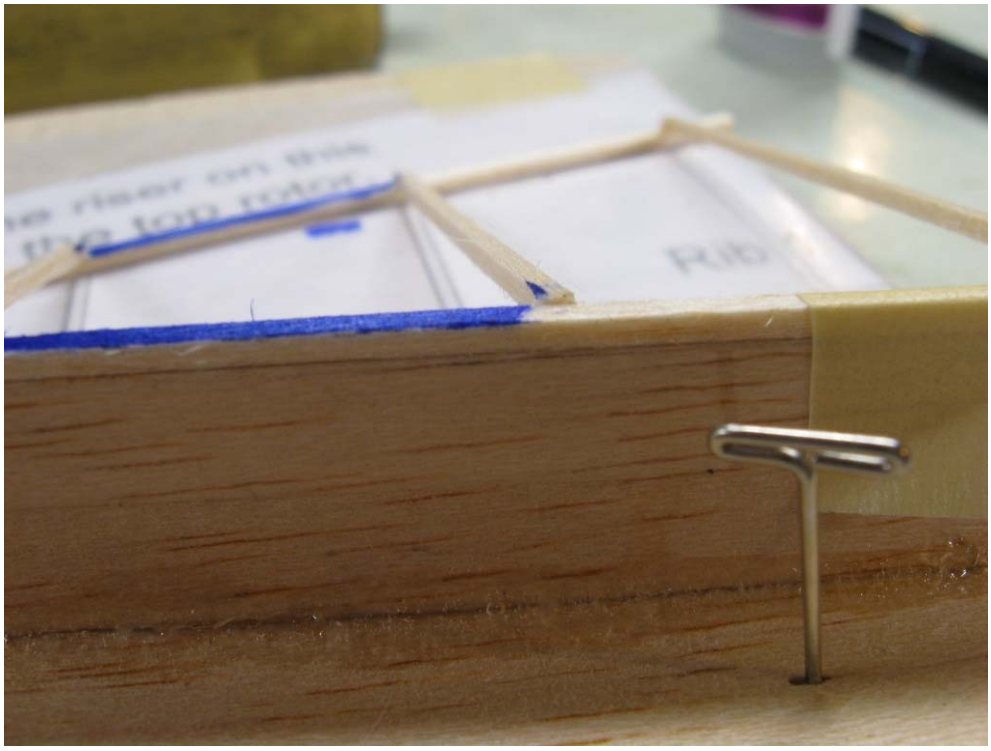


Note the gap at the top of the hub. While it would be nice if it was not there, this will give an idea how much error can be acceptable,

Step 6 Removing the rotors from the Building Board
First gently remove the 4 pieces of tape that hold the top spar to the risers. (The spar will most likely be glued to the riser. We’ll take care of that shortly.)
Some of the 1” Tee Pins will be glued to the ribs and lower spar.
DO NOT PULL THE PINS OUT! ROTATE the 1” Tee Pins **BEFORE** you pull them out of the Building Board. Once they rotate freely then you can pull them out gently. If the spar lifts off the waxed paper make sure the pins rotate and hold the lower spar down as you remove the pins.
Remove the push pins that held the lower spar in place.

Remove the pins (or weights) that hold the risers in place.
DO NOT MOVE THE ROTOR YET!.
Slide the corner of a thin piece of stiff paper or plastic (business card, credit card, driver's license) under the lower spar between any two ribs. Gently slide it to each end and center of each side of the rotor. This will break loose any glue that has attached the spar to the waxed paper. Now that the lower spar is loose you can check to see where the ribs on the upper spar are attached to the risers. Carefully break the glue loose from the risers until the rotor is free. Look at the picture below. The razor blade was inserted between ribs 2 & 3 and is being pushed from left to right to break the glue loose at the ribs.

Step 7 Trimming and sanding the rotors.
No matter how careful you were attaching the ribs to the spars there will be some bumps and bits of glue that need to be removed before the rotor is covered with plastic film.



Now is the time to trim the ends of the spars flush with the ribs. Be sure to support the spars as you cut the excess off. Once this is completed take the nail file and smooth any raised pieces and sharp corners that might tear the film. As when you sanded the ends of the ribs use a gentle touch.

Step 8 Covering the rotor using a glue stick

Included with this information pack is an article on how to cover with film using a spray adhesive such as 3M® 77. I prefer to use a glue stick because the film can be repositioned (correct a mistake) unlike some of the sprays.

Cut a piece of kitchen plastic wrap about 18” long. Cut this into 4 pieces approximately 6” X 9”.

Take one of the pieces and smooth it out on a flat surface with one of the 6” edges at the edge of the flat surface.

Before applying adhesive to the rotor, practice placing the rotor on the film and rotating it so the upper spar is the only piece contacting the film. Next, practice rolling or rotating the rotor so Rib#1 contacts the film, then the lower spar. Do this a few times because once the film is stuck to the wood, removing it is not fun and you stand a chance of breaking the rotor.

Apply the adhesive to the top surface of the spars, rib #1 and rib #5 on one side of the rotor. (You marked these surfaces in Step 4 so they are now easy to identify.)

Place the rotor onto the film so the upper spar only contacts the film. Gently press the back side of the spar to the film.

Now rotate the rotor so rib #1(the first spar should still be on the flat surface) is in contact with the film and press this to the film.

Rotate the rotor so the lower spar contacts the film. (The film has lifted off the table where it is attached to the other spar and rib #1.) Press the spar to the film.

Lift the rotor off the table and attach the film to rib #5 by squeezing the rib between your finger and thumb.
Since this is harder to describe than it is to do, there is a short video on the CD that shows the covering being attached to the rotor.
Hold the rotor so the excess film falls away from a spar. Apply adhesive to the exposed surface and then attach the film. Do this for the other spar and ribs 1 & 5. Trim the excess film from the rotor using a razor blade.
Repeat this for the other side of the rotor and the other rotor.

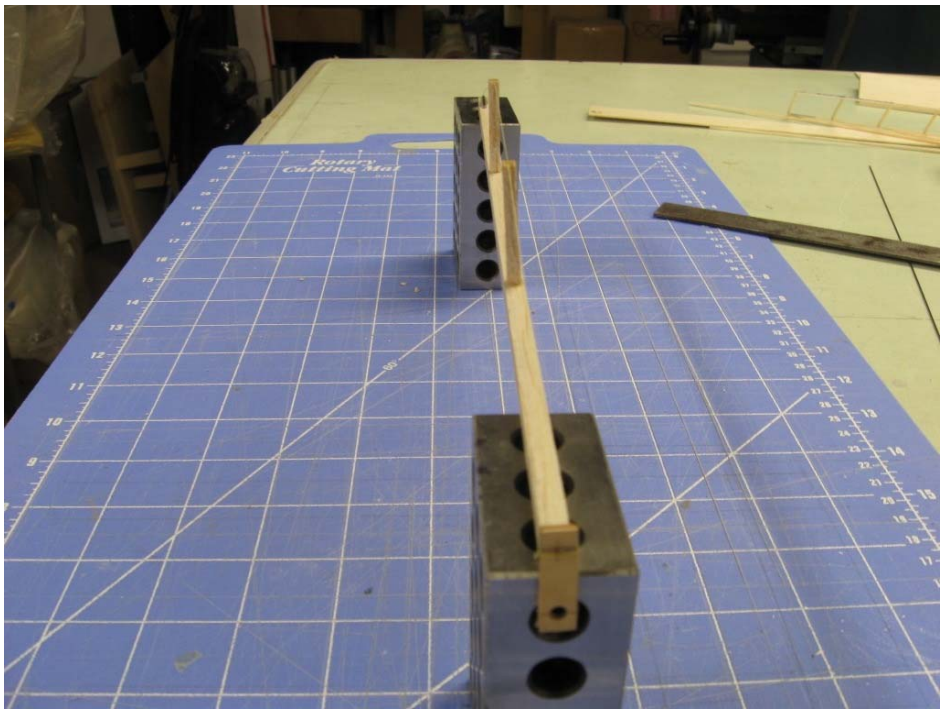
Step 9 Attaching the Rotor Shaft to the Top Rotor.
It is VERY IMPORTANT to take your time to get this right.
Locate the Top Rotor and its lower spar. The lower spar should have the center marks you made to help locate the rotor hub. These marks will now be used to locate the rotor shaft. (If you use the Bottom Rotor you will need to wind the rubber in the opposite direction.) Take a piece of stiff paper about 2” X 2” and cut out a rectangle about ¼” X ½” in the middle of one edge.
Hold the top rotor turned upside down. Place the rotor shaft on the spar so the 90° bend is at the center mark on the spar. The bare leg should be centered in the width of the spar. While holding the shaft on the spar, use your other hand to place the paper along the hub and shaft. (The cutout in the paper will allow for clearance for the hardware.) Make the rotor shaft parallel to the edge of the paper. Have your other team member place a SMALL drop on glue on the leg of the shaft resting on the spar.

Do not get glue on the black glass bead, the Teflon washer, the white nylon thrust bearing or your fingers. Allow the glue to dry while holding the shaft in position. Once the glue is

dry recheck to ensure it is parallel to the hub. Once satisfied with the alignment apply a coating of glue along the length of the bare wire on the spar and allow it to dry.
Hold the rotor by the white plastic thrust bearing and you will notice one blade always goes to the bottom. The rotor is out of balance and the bottom blade is heavier than the top blade. Cut a piece of masking tape about 2” long. Press the adhesive side to your shirt or pants to reduce the strength of the adhesive. You want this to just barely stick to the top blade. Hopefully this amount of tape will make the rotor rotate and the blade with the tape is now on the bottom. If it does not rotate add another piece of tape. If it rotates with the first piece of tape, use scissors and start to cut off small pieces of tape until it rotates again. Do not be surprised if it only rotates 90 degrees and is horizontal. Cut a new piece of tape the size of the one that rotated the blade. Attach it to rib #1 on the light blade. Fold the tape over so it is on both sides on the blade. If more than one piece of tape was needed, use a scale to get the weight of the tape. Depending on how much weight is needed you can glue a small piece of ballast (wood, plastic, wire or etc.) to the inside of rib #1.
If you wish to test fly the helicopter in a low ceiling room it is wise to add a “Bump Stick”. This is a piece of 1/16” X 1/16” X 3”-4” balsa glued to the top rotor hub. The stick will hit the ceiling before the rotor and keep the rotors from breaking.
If the blade remains horizontal you can experiment with adding weight to the top corners where the spars join the #1 ribs. Do not bother with this until you have made some test flights as this direction of balance is not as critical as the previous one.

Step 10 Assembling the Motor Stick
Locate the 3/16” X 1/4” X 12” stick the 1/16” X 1/4” X 1” Predrilled Plywood Thrust bearing mount and the rear rubber hook.
The thrust bearing mount is glued to one end of the motor stick. Place a Tee pin through the small hole in the mount. Hold the pin on the 3/16” wide side of the stick.
Apply a drop of glue to the end of the stick and glue the mount to the stick.

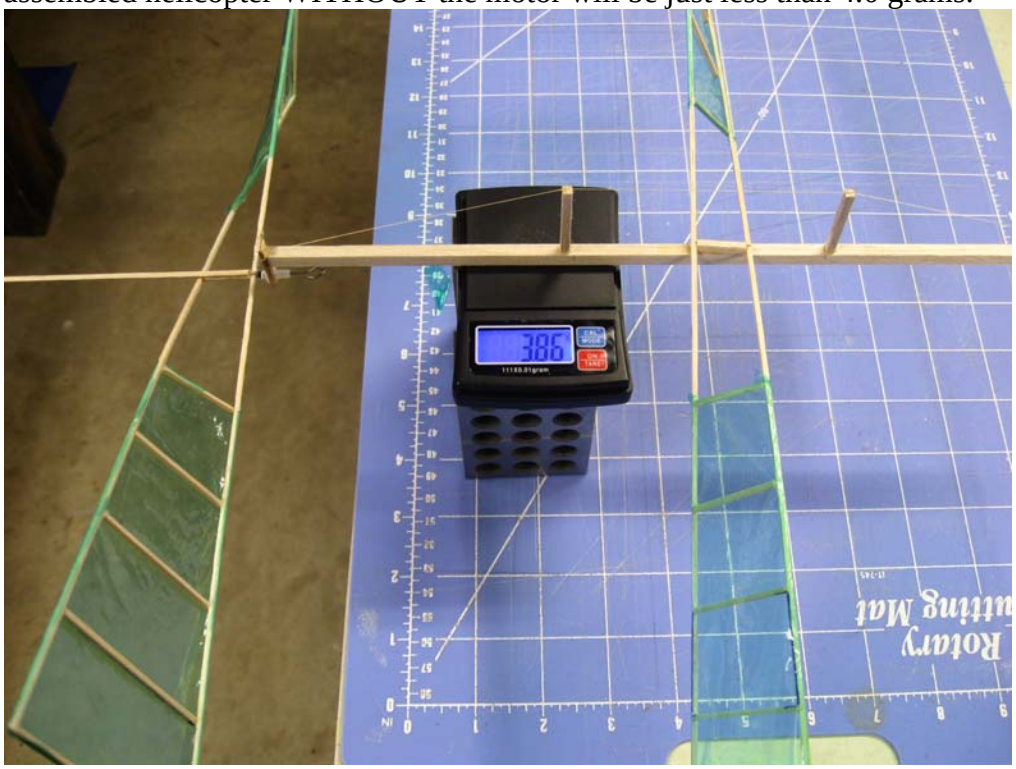
On the opposite end of the stick press the short leg into the same side of the stick you rested the pin on. This will position the circular wire loop on the same side of the stick as the large hole in the thrust mount. Apply glue to the wire where it contacts the stick.
Locate the two 1/8” X 1/8” X 1 ¼” bracing posts. Look at the plans and glue them on the proper side and locations. Place a little glue on the tops of both bracing posts so the thread will not cut into them. It is more important that they are vertical and in line with each other than where they are located.
Tie a piece of thread to the rear rubber hook and glue it to the end of the stick. Once the glue is dry, pass the end of the thread through the small hole in the thrust bearing mount. Set the thread on the tops of both bracing posts and pull it taught enough that the motor stick just barely begins to bend. Make a couple of loops around the thrust bearing mount and glue the thread to the thrust bearing mount while keeping tension on it. Once the glue is dry, apply glue to the tops of both bracing posts. This thread will counteract the force of the rubber motor. Without it the motor stick will break from the force of the rubber.



Step 11 Attaching the Bottom Rotor
If you look at the plans you will see the bottom rotor is in the center of the motor stick between the stick and the bracing thread. Its exact position is not as important as its alignment. That said attaching the bottom rotor to the motor stick is an ideal application for the use of acetone based glues like Duco and Ambriod. The bond formed by these glues can be softened with acetone making repositioning of the bottom rotor very easy compared to using other adhesives.
Mark the area on the stick where you plan to place the rotor. Again this should be on the surface directly under the thread between the two bracing posts. Orient the bottom rotor so you have the film on the upper surface. The rotor will be glued to the stick with the film on the side nearest the thrust bearing mount. Test fit the rotor to the motor stick. Use

the clothes pin clamp to hold the hub to the motor stick. The rotor needs to be glued at right angles to the stick. Before trying to glue it in place determine how you will align it and make certain you are happy with the result.
Apply glue to the rotor hub and slide the rotor under the thread into position. Clamp the hub to the motor stick and allow it to completely dry.

Step 12 Final adjustments
Insert the top rotor into the thrust bearing mount by carefully threading the wire rotor shaft through the hole.
The top rotor should spin freely and perpendicular to the motor stick. If it is not perpendicular due to the bend in the rotor shaft adjust the bend by holding the spar and wire between your fingers with one hand and the white thrust bearing in the other hand. VERY CAREFULLY bend it in the direction required. Small pliers can also be used but hold both legs of the wire. If you don't hold both while trying to bend the wire, either the spar or thrust bearing mount will break.
Place the completed assembly on a scale that you know is accurate. (If you are in doubt ask some one to help you calibrate the scale with a set of test weights.) Ideally the assembled helicopter WITHOUT the motor will be just less than 4.0 grams.



Add clay ballast to the bottom of the motor stick until you reach 4.04 grams.
It will be very difficult to wind the rubber motor with the propeller. I really suggest using a rubber winder.
Many articles have been written about winding rubber motors so I will not address that topic with these instructions. With the CD are a couple of articles on winding rubber and adjusting motors.

Step 13 Flying

Before you transport you helicopter outside you will need a box of some type in which to carry it. If it is windy or raining outside the helicopter can be ruined by the elements in seconds. A pizza box with raised side and a lid can do the job.

When you pack the helicopter to go to a flying sight also pack a tool/repair kit. This should contain a couple of pieces of wood, plastic covering, glue, tape, clay ballast, a couple of paper towels and any other items you might need to perform a "field repair" so you can keep flying. Along with this tool/repair kit you should have your winder, rubber lubricant, spare rubber motors, flight log and pen or pencil. Make a check list for these items so you can be sure you have everything you need.

Once the motor is wound and attached to the rotor shaft and rear rubber hook you are ready to launch your helicopter. **DO NOT THROW IT INTO THE AIR!**

Hold the top rotor with one hand and the bottom of the motor stick with the other. Release the top rotor and allow it to start spinning. After a second or two the top rotor will reach its maximum rotation speed and you can release the motor stick.

Trimming

With this design there are only a few options for trimming.

This design does not provide a means to adjust the pitch (angle of attack) of the rotor blades. This was determined when it was built. To obtain different pitch blades new rotors will need to be made. The same plan can be used with different height risers. The length of the ribs would need to be adjusted also. For those who want to experiment the original AutoCAD® .dwg file is included with the CD and a like to free CAD software that can be used to edit the drawing is included. I do not recommend this approach. I believe the designs that will soon be available will be a better investment of time.

The main method to optimize flight times will be through adjusting the length of the rubber motor. Ideally the helicopter should land just as the rubber completely unwinds. If there are still turns left the motor can be shortened. If it runs out of turns while still at altitude the length can be increased. Just remember not to exceed the 2.0 gram maximum for the motor.

It is also important to lubricate the motor. Armor All is a favorite. Spray it on the motor before you wind it.

We anticipate commercially produced kits will soon be available from a number of sources.

Additional sources for information.

www.indoorduration.com
http://www.indoorfreeflight.com/
http://freeflight.org/Community/links.htm
http://www.aeroaces.com/
http://www.3ds.com/products/draftsight/#vid1 free software to edit the .dwg drawing

More information will soon be posted on the Maryland Science Olympiad web site so please take a look at it periodically.