Plans for a homemade Dobsonian telescope

Since you are reading this, you are probably considering to build your own Dobsonian telescope.
This page provides detailed plans and instructions how to build one.

You can buy some ready made parts, or you can make everything on your own, including the mirrors and eyepieces.

You can follow the instructions strictly, or make modifications to suit your needs, available materials, and skills.
The design described here works very well for more than 40 telescopes I have built either for myself, fellow astronomy club members or educational projects.

What is an Dobsonian?

It is an Newtonian optical tube, mounted on a very simple, yet very stable and easy to use alt azimuth mount. The mount works via friction, just little enough to easily move the telescope, but yet enough that the telescope remains pointed. It is held together by gravity alone. This mount was invented by John Dobson, a member of the San Francisco Sidewalk Astronomers. It was first referred to as the "sidewalk telescope". Its main goal was to make astronomical observations affordable to anybody, by using this cheap, easy to make telescope.

What size should I choose?

Presented here, are the 2 most common sizes, 150 mm (6") and 200 mm (8") primary mirror diameter.
Besides the primary mirror diameter, there is another important parameter : the focal length.
Commonly available are 150 mm primary mirrors at f8 (1200 mm), f 6.7 (1000 mm) F5 (750 mm),
and 200 mm mirrors at f6 (1200 mm) and f5 (1000 mm)
The mount presented here **can not** accommodate the 200 mm f 8 (1600 mm FL) tube.

Most popular are the 150 mm F8 and the 200 mm F6. Both are universal telescopes, equally good both for planetary or deep sky observations. Going for a shorter focal length will give you a shorter, more compact tube, easier to transport. On the other hand, the faster focal ratio will want more expensive eyepieces, and is more demanding on collimation. The 150 mm will be cheaper and lighter, but the 200 mm gathers more light and will show more deep sky objects.. for a higher price, and more bulk and weight.

Materials and tools needed:

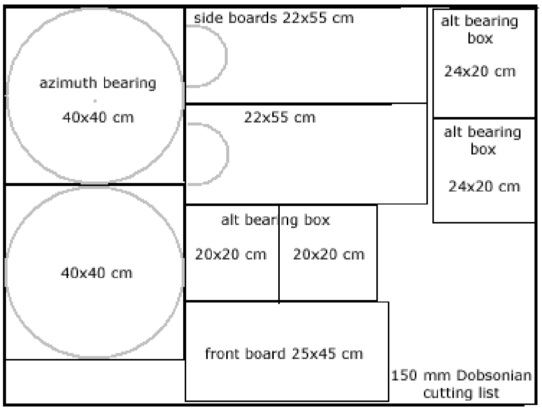
The most important components are the optics, primary and secondary mirrors. Buy those first. For a 200 mm F6 primary, a 40 mm minor axis secondary is needed. For the 150 mm F8, a 32 mm secondary.
You will also need at least one eyepiece, and a finder scope.

Besides that, the rest of the telescope are boards, a tube, a handful of screws and couple more easy to find items. You might buy a ready made focuser, spider and primary cell... or make your own. Same with eyepiece's and finder scope.
A drill, jigsaw, and some simple hand tools is all that is needed.

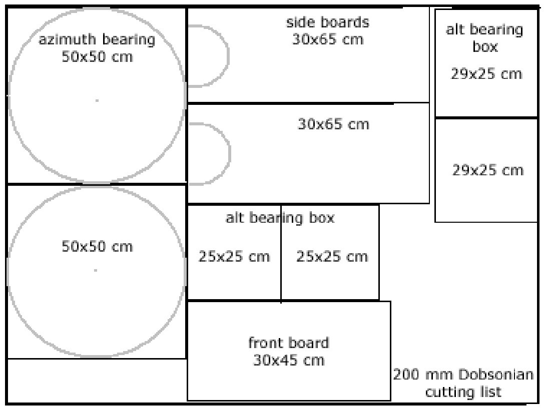
Lets start with the MOUNT:

The mount is made from standard 19 mm particleboard. It is cheap and commonly available. In most shops, you can bring a cutting list, and you receive ready cut, square pieces. Pick any color you want, or, you can buy the small cutting leftovers very cheaply. You will get boards in a few colors and patterns... but all it takes is one can of spray paint to paint it. You have to paint it anyway, to make it moisture resistant. Out there, at night, it can get very wet. You can also make this mount out of 19 mm plywood, or laminated wood.

Cutting lists :



150 mm mount

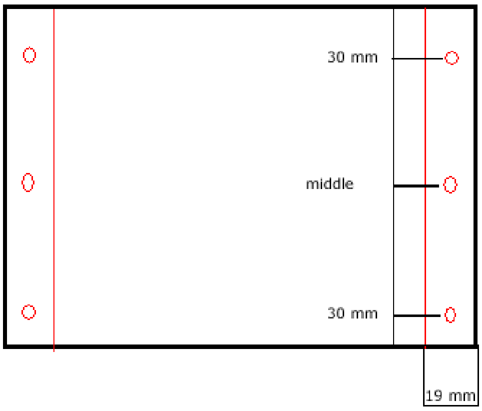


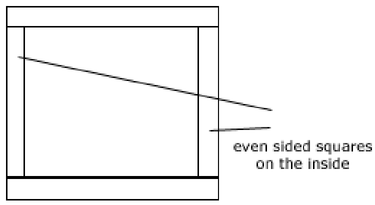
200 mm mount

At this point, you can also buy the tube, and the altitude bearings. For this telescope, you need a PVC drain tube.
If you have a 150 mm F8 mirror, a 200 mm OD tube is needed. Unfortunately, the standard sizes are 1 and 2 meters in length.
If you can find a scrap piece about 120 cm long, that would be just right. The f6.7 and the f5 focal ratio fit the 1 meter tube.
Same goes for the 200 mm mirror, only here you need the 250 mm OD tube. Also, around 120 cm long. The f5 will (barely) fit the 1 meter tube.

Assembling the altitude bearing box

Lets start with the easiest part, the altitude bearing box. Simply, it is a frame that is holding the tube, and the altitude bearings are mounted on it. First, mark your drilling holes. Since the board is 19 mm thick, draw 19 strips on the wider side of the board :



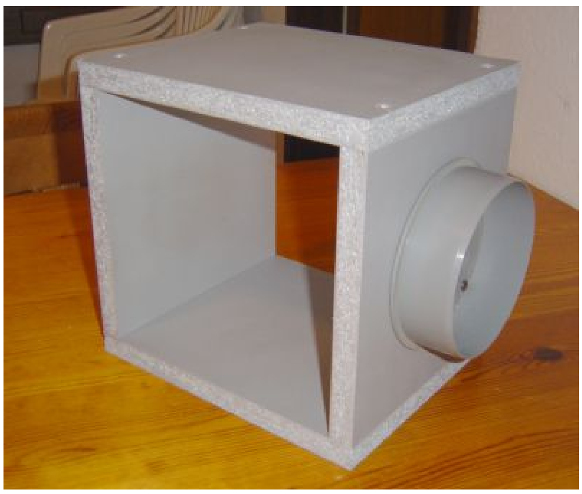


Mark 3 drilling holes per strip, 30 mm from the edges, and one in the middle. Use a 4 mm bit for the holes. You also need to sink in the screw heads. There is a special tool for this... but you can do it with a 10 mm bit, with your hand. Do the same on both boards. The even sided boards do not need drilling.

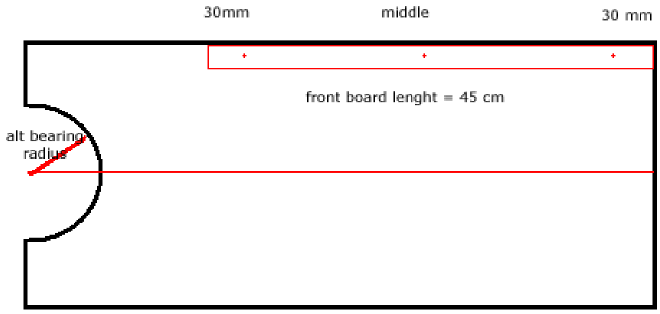
For assembling the box, right angle clamps would be handy, but not necessary. Use 4x50 mm wood screws, and some carpenters glue in-between the contacting surfaces. Done :)

You can paint the box, and mount the altitude bearings. It is important that the center of the PVC plug is mounted at the center of the even sided square of the box. Usually there is a mould mark at the center of the plug already. Drill a 4 mm hole in the center, and find the center of the even sided boards by drawing diagonal lines, corner to corner. The intersection is the center of the square. To attach the PVC plug, use 4x16 mm wood screws, 3 per plug is enough.

This is how a finished altitude bearing box looks like :

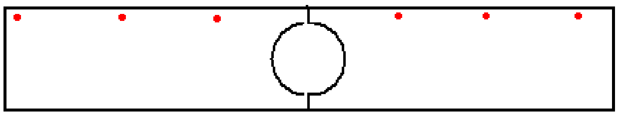


Preparing the sideboards



First, we need to draw a line across the middle of the board. This line enables us to draw the altitude bearing cutout, and later, to align the mount on top of the altitude bearing. PVC plugs are cheap and work very nicely as altitude bearings. Either the 125 or 150 diameter plugs will work nicely on both mount sizes.

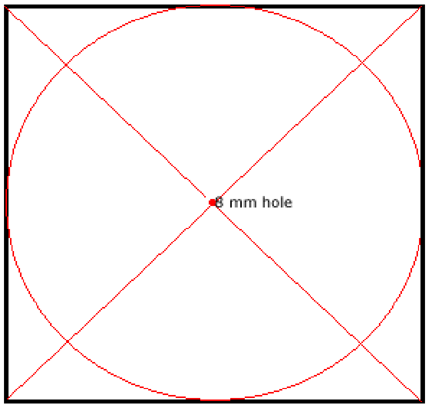
The alt bearing cutout should be slightly larger than the PVC plug itself, about 3 mm, to provide space for the felt pads, which the PVC plugs ride on. For a 125 mm plug, use 64 mm RADIUS.



After making the cutout, draw a 19 mm strip , 45 cm long, on the further side of the sideboard (refer to picture above) Again, use a 4 mm drill bit, and sink in the screw heads. But, here you have one left side and one right side board. The bearing cutout is the same, drilling holes too... only sinking in the screws is done on the opposite side. Put both your board on the table, or floor like on the image:

Now sink in the screw heads , and you will get one right side and a left side board.

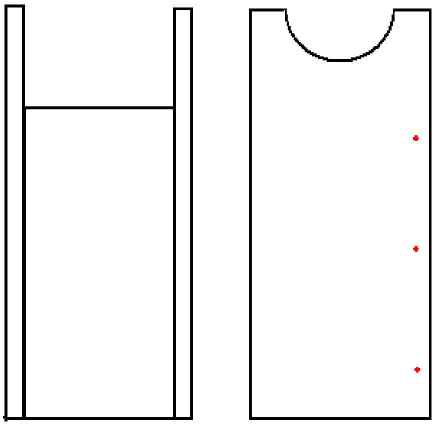
Preparing the azimuth bearing boards (ground boards)



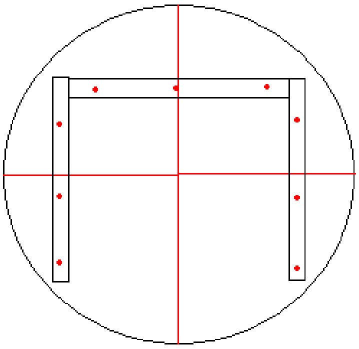
First we need to find the centers of the boards. This is easily done by drawing diagonal lines. The lines are not only to find the center, they will be used to align the top piece of the mount on the azimuth bearing, so draw them in full length. In the center, drill a 8 mm hole. It is very important that the hole is vertical relative to the board, since this is the axis of the azimuth bearing. A drill press would be nice, but it can be done freehanded if you are careful. Next, we improvise a large compass.

Take a old ruler, or a piece of wood, drill the same 8 mm hole at one end, put the M8x60 screw trough and drill a small hole (4 mm is fine) at the outer edge of the board. Draw the circle and you are ready for cutting. A router with a compass would be perfect for this job, but it can easily be done with a jigsaw too.

Assembling the mount



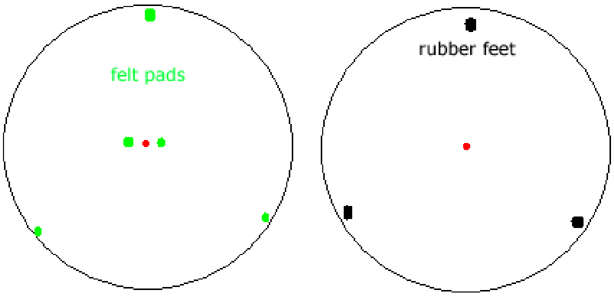
First we need to assemble the top part of the mount. Two sideboards, and a front board.
Again, use 4x50 mm screws and carpenters glue.



Take one azimuth bearing board, and put the upper part of the mount on top, aligning the marks on the boards you draw earlier.

Draw the outline of the upper part of the mount on the azimuth bearing board. Mark your drilling holes, as per sketch above. You also need to sink in the screws, do it well on this board, because the azimuth bearing will not be able to rotate if the screw heads are sticking out. You should sink in the screws on the OPPOSITE side of the outline drawn. To put everything together, place the upper part of the mount with the altitude cutouts downwards, and put the azimuth bearing on top. Apply some glue, align the azimuth board and screw everything together with 4x50 wood screws.

We have one last remaining azimuth bearing board.



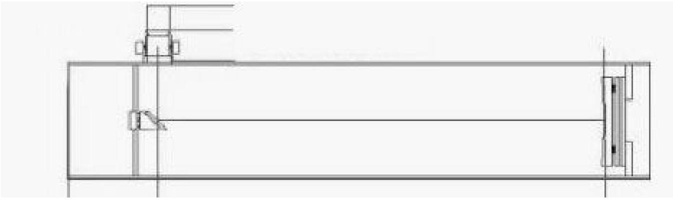
On one side of the board, put 5 felt pads, the same one used on furniture feet.
Put 3 on the outer edge of the disc, 120 deg apart, and 2 near the 8 mm axis hole (green dots on sketch above)
On the other side of the board, attach 3 rubber feet, near the edge, 120 deg apart.
They need to be at least 25 mm tall to provide enough clearance on uneven ground. The upper part and the ground board are rotating around a M8x60 screw that we put trough the center holes.
Use oversized washers on each side, and a self-locking (Nylock©) nut.

The bolt head should face the ground. The tension should be just a little that the boards are connected together.. but not too tight.. so they can rotate freely. This can be adjusted at any time... and will probably be necessary after a couple of months of use, because the felt pads will compress under the weight of the telescope.

To provide a bearing surface for the altitude bearings,
4 more felt pads are needed. (picture on the left)
This is how your brand new, finished Dobsonian mount looks like.
The hole in the front board is optional, this way it is easier to carry the mount.

If you are handy with the jigsaw, and want your mount to be lighter and easier to transport, you can cut out the mount like on the picture below. Also, installing a handle on the altitude bearing box will make transporting and setting up your telescope much easier.

Now that we have a nice and stable mount, we can continue building the optical tube assembly (OTA)



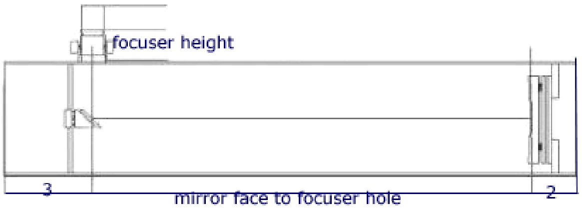
The optical tube assembly (OTA)

This is the raw PVC sewer pipe , originally intended for a job not so glorious , but you can give it a much more noble purpose by turning it into a precision astronomical instrument :)

PVC tubes are tough, easy to work with and relatively cheap. They are also a thermal insulator, your telescope will be much less sensitive to dew than the one with a metal tube.

Start with cutting off the wider part of the tube. This is easily done with a jigsaw. Mark your line around the tube, drill a 10 mm hole next to the line (on the part that is wasted!) put the blade in the hole and cut the tube. Use flat black spray to paint the inside of the tube and let it dry.

Dimensions :



	150 mm F8 primary mirror	200 mm F6 primary mirror
focuser height	100 mm	100 mm
mirror face to focuser hole	1011mm	993 mm
mirror cell height (2)	90 mm	90 mm
focuser to front of tube (3)	100 mm	120 mm
total tube length	1200 mm	1203mm

The parts dimensions listed here are more or less typical. If you make your own mirror cell by the plans provided here, and your mirror is 20 mm thick, the mirror cell height (including mirror) will be 90 mm. If your mirror is 30 mm thick, you will have to add 10 mm to the "mirror cell height" All other dimensions remain the same. But if your focuser is different as the 2" , 100 mm tall Meade DS described here, you will have to alter the "mirror face to focuser hole" dimension.
Example : A low profile helical focuser is typically 50 mm tall, this means you need to ADD the difference of 50 mm into the "mirror face to focuser hole". As a consequence , your tube total length has grown by 50 mm. If your focuser is taller, 120 mm for example, you need to subtract the 20 mm difference from the "mirror face-> focuser hole" dimension. The part of the tube pass the focuser (labeled 3 on the drawing) is not critical.. but you will want at least 100 mm here, or even better, 200. This prevents a lot of stray light that comes from streetlamps etc to interfere with the light coming from the stars. If your cargo space is tight, you can cut the tube just behind the spider vanes.... but it is recommended to make a removable dew and light shield out of cardboard or similar that you can attach on the telescope at the observing site.

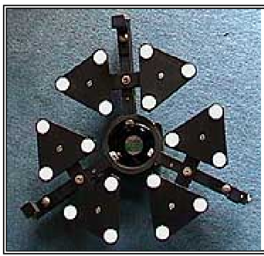
The focuser, commercially made

This is the focuser I used on most of the telescopes I built. It is a Meade 2" DS series focuser. It comes with adapters for 2" and 1.25" eyepieces. At 19$, it is a good value for the money, although it is not a high end product, but it will serve its purpose very nicely. Highest quality products like can easily cost a couple hundred $. Alternatively, you can buy a 1.25" or 2" rack&pinion metal focuser at the

Homemade focuser

This is a 2" helical focuser made out of common plumbing parts. This particular item is called "toilet flush valve" and it will cost you around 6$. If the saved 10$ is worth the effort, it is up on the telescope builder to decide. An even simpler focuser form is the drawtube focuser. Basically, it is made out of 2 tubes, usually plastic, that fit into each other, and the top tube has 1.25" ID. It can even be made out of cardboard.
Another alternative is the

Mirror cell , commercially made



Commercially made, fancy, high tech mirror cells are very expensive.
The one in the picture, 200 mm mirror size, will set you back 220 €!

Homemade mirror cell

This is a homemade mirror cell. Basically, it is made of 2 particle board discs, 6 screws and nuts, 3 compression springs and 9 felt pads. How much does that cost? 10$? :) This is one of the parts that really saves money if homemade! And it works the same! A typical 150 or 200 mm mirror is thick enough not to require a floating mirror cell like the one above.

Spider, commercially made

A commercially made spider can cost you anything in-between 20 and 200$. But it can also be easily made.

Homemade spider

Hmm... what do we have here? A short piece of plastic tubing cut at 45 deg, a plastic hexagonal male-female adapter, 3 small woodscrews, 3 hacksaw blades and 3 screws :)
Voila, a spider ! This is how it looks like mounted in the tube.

The curved spider vanes give a spike-less image

Eyepiece and finder scope

To observe with your telescope, you need at least one eyepiece.
If you are in doubt which one to buy, you can't go wrong with a **26 mm Plossl**. This is a good, primary, low power eyepiece for your telescope. It will give you 50x magnification with the telescopes described here.
And to observe, you also need to aim the telescope at the object you wish to see. I would recommend a **8x50** finder scope, (esp. for the 200mm scope) but a smaller one, 6x30 will also do.
If you are on a tight budget,

Drilling the focuser hole

The best tool to make the focuser hole is the hole saw. For the Meade 2" (and most other 2" focusers) you will need to make a 60 mm hole. Measure carefully. For 1.25" focusers, you typically need a 40 mm hole. The "mirror face-> focuser hole" distance from the table above refers to the CENTER of the focuser hole, not the edge!

Also, make sure to secure the tube **FIRMLY** with a clamp to your workbench. Drill **SLOWLY** (low RPM) and **GENTLY** (the weight of the drill is too much.. hold it up, the saw should barely glide on the tube)
This way you will make a clean cut hole, with a low injury risk.

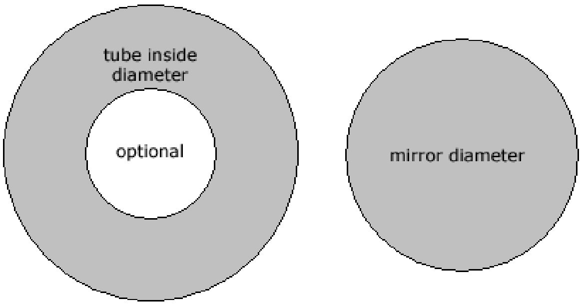
Alternatively, you can draw a 60 mm circle, and drill many small holes along the line. You can make this "toothy" hole clean with file and sandpaper

In addition to the main hole, you will need 3 or 4 small holes, for the screws to mount the focuser on the tube. Their number and position depend on your particular focuser.

Plans for the primary mirror cell

		
Top view	Side view	Rear view

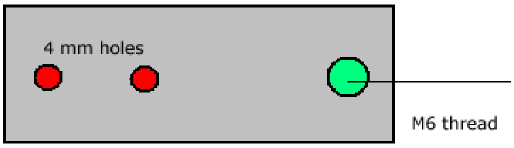
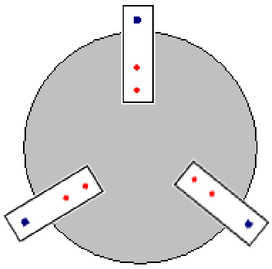
This is how our simple, but fully operational mirror cell looks like. Basically, it is made out of 2 particle board discs, the top, smaller one having the same diameter as the mirror, and the larger, that will cover the rear of the tube, has the same diameter as the **inside** diameter of the telescope tube. You can see 3 bolts with springs. These are used to adjust the aim of the mirror, or **collimation**.
This is essential for good quality images in the eyepiece.



Lets cut the particle board discs first. Optionally, you can cut out a 80 mm opening in the "tube board" and install a 12 V cooling fan, from a PC power supply for example.

The fan speeds up the cooling down of the mirror. Now is a good time to check if the "tube board" fits inside the end of the tube snugly.

If its too large, work the edge with rough sandpaper. If its too loose, you can wind a couple of turns of electricians tape around the edge until you have a snug fit.

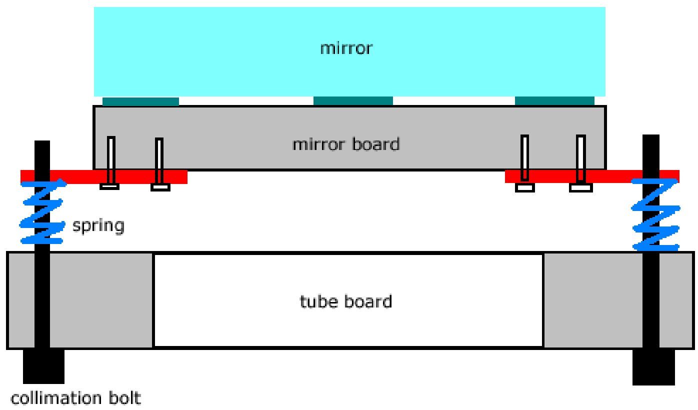
		
For this part, you can use any flat piece of metal, at least 3 mm thick. On it, you need to drill two 4 mm holes, so you can attach it to the mirror board with 4x16 woodscrews. On the other end, drill a 5 mm hole, and tap in a M6 thread. You need 3 such pieces.		Attach the 3 plates to the "mirror board" with screws, 120 degrees apart. Make sure that the part of the metal plate does not stick out more than the diameter of the "tube board"! Example : Mirror board diameter 150 mm Tube inside diameter 190 mm Max overhang 15 mm (you need some clearance)

Now, put the "mirror board" on top of the "tube board" , center over center. Trough the M6 threads, mark the drilling holes for the collimation bolts. Try to be as accurate as you can. Remove the mirror board and drill 7 mm holes on the marks. Use a drill press if you have one. Paint the mirror cell parts flat black.

Assembling the mirror cell

Installing your mirror is the LAST thing to do!

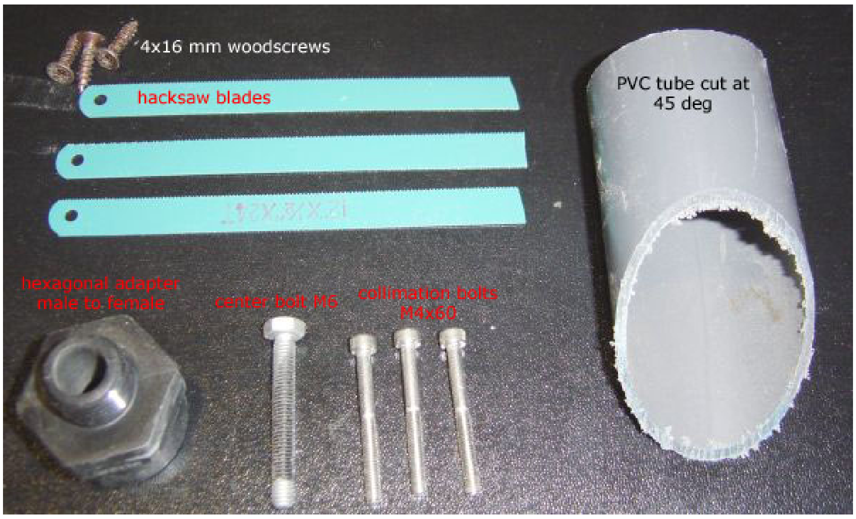
Take a collimation bolt (M6x60) , put a washer on it, slide the washer to the bolt head and put the bolt trough the hole on the "tube board".
Now put another washer on it, and the compression spring on top of it.



Take the mirror board, and screw the collimation bolt in the thread, just a few turns.
Do the same with the remaining bolts and springs.
Now tighten the collimation bolts so that the springs get about 1/3rd compressed.

Try to tighten them evenly, check if the boards are parallel You have just made yourself a mirror cell :)

Homemade spider (secondary mirror holder)

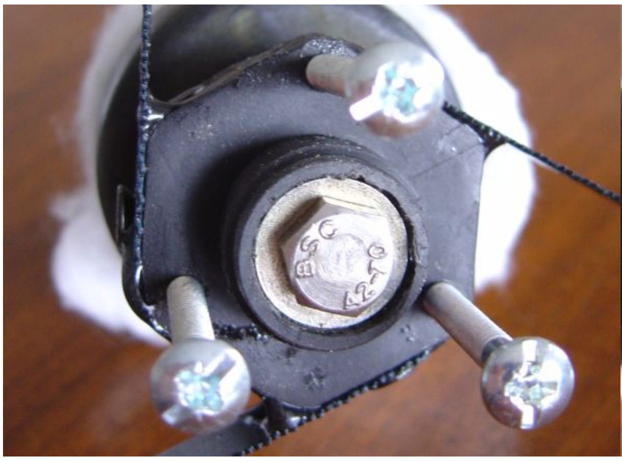


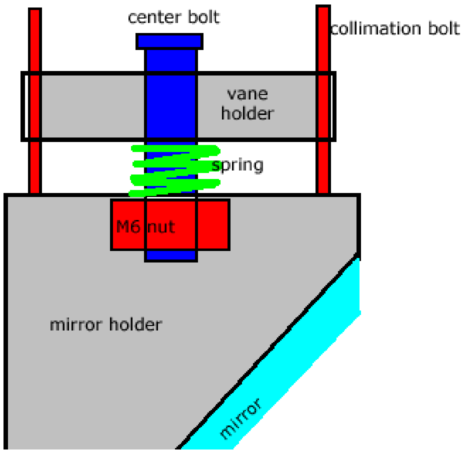
These are the "raw components" for our telescope spider. Missing in the picture is a compression spring**.** PVC tube diameter should be the same, or slightly smaller than the secondary **minor axis.**

Hacksaw blades can be "cut" to length by holding the blade at the point where we want to shorten it in a vice or pliers and simply brake it off.
This is easy, hacksaw blades are very brittle.

After we cut a piece of PVC tube at 45 degrees, we need to close the tube openings. You can, for example, use a empty CD box, cut approximately sized (larger) pieces, glue them with epoxy resin on the PVC tube and then sand off the excess plastic. But, before that, epoxy a M6 bolt on the center of the part that is cut perpendicular. This holds the center bolt and the spring so you can adjust the "vane holder --> mirror holder" distance. The 3 collimation bolts tilt the mirror holder, so the telescope can be collimated.

On the hexagonal adapter, drill three (picture below) 3 mm holes in the corners and tap in a M4 thread. This is very easy in plastic.
Attach the spider vanes (hacksaw blades) to the flat surfaces of the hexagon (vane holder) with the 4x16 woodscrews, trough the holes already in the blade. Secure with a drop of epoxy resin.



Inside life of the spider assembly

Now we have all the parts needed to assemble the telescope! :)

Almost there :) A few more steps and you will have a complete, working Dobsonian telescope!

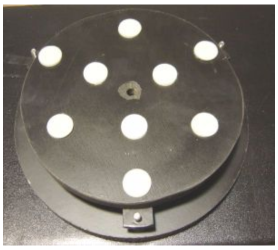
Mounting the focuser

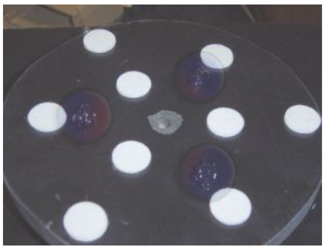
This is a fairly simple affair. Align the focuser over the center of the focuser hole, mark the drilling holes and drill 2 mm holes for the screws, if you use woodscrews (works very well on PVC) Or, you can drill larger holes and use bolts and nuts to attach the focuser.

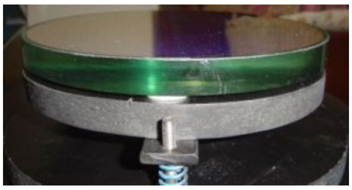
Mounting the mirrors

A word of caution: NEVER touch the aluminized surface of the mirror!

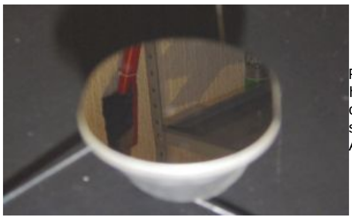
Lets start with the primary mirror. Put your mirror cell on a table, or other leveled surface. Use 9 felt pads to provide a soft surface for the mirror to rest on. Then make 3 blobs of aquarium grade silicone on the surface of the cell. Carefully unpack the mirror and place it centered over the mirror board. Cover your mirror with cotton or a soft cloth to protect it. Leave the silicone to cure for at least 24 hours.







Mounting the secondary mirror

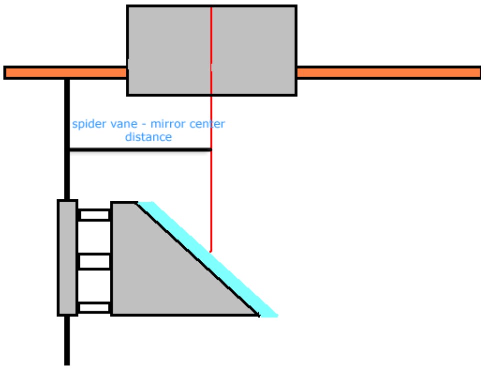


Place the secondary holder that the surface for the secondary mirror remains in a horizontal position. You can clamp the spider assembly in a vice or similar. Apply a coin size aquarium silicone blob at the center of the mirror holder, and place the secondary mirror carefully and centered over the holder. Adjust if necessary. Again, leave the silicone to cure for at least 24 hours

Mounting the spider

This is a typical commercially made spider.
Basically, you need to drill 3 or 4 holes (3 or 4 vane spider) to be able to attach it to the tube wall.

But where?!



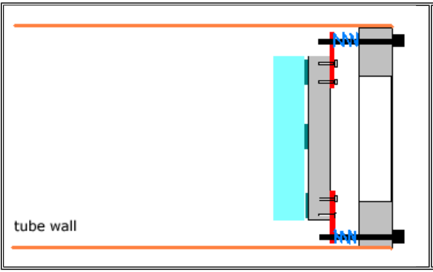
You need to measure the distance from the center of the secondary mirror to the spider vane. Now, measure the same distance from the center of focuser hole, towards the front end of the tube. Dill your holes here.

This way, when you mount the spider , the center of the secondary mirror will be exactly, or very nearly centered under the focuser. You can make adjustments for this with the center bolt on the spider assembly.

Mounting the homemade spider

No holes. No bolts. The spider you made is a self holding, self centering, curved vane spider. As most observers agree, it is optically superior to a classic, straight vane spider, especially when observing the planets or double stars at high power.
All you need to take care of is that the spider vanes are touching the tube wall at 120 degrees apart.
You can remove it in matter of seconds. The spider is held in position by the tension of the bent spider vanes alone.
I have such a spider in my telescope for over 2 years now and it has not moved since.
But, if you feel uncomfortable about this, apply a few drops of epoxy resin on the contact points with the telescope tube once you have adjusted the position of the spider vanes.

Mounting the primary mirror cell



Homemade or commercial, you need to attach the mirror cell to the back side of the tube. To attach your homemade cell, all you need to do is to drill three 4 mm holes, 120 degrees apart, 9 mm from the edge of the tube. Sink in the screws heads. Put the mirror cell inside the tube, and place the collimation bolts away from the holes you drilled to attach the cell to the tube. Use 4x 20 mm woodscrews to fasten the cell.

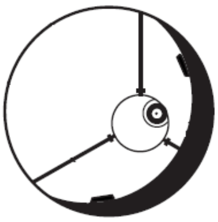
For a commercially made cell, refer to mounting instructions of the manufacturer

You now have a complete OTA.
Now, you can attach your finder scope, and put the tube inside the altitude bearing box. Also put the eyepiece in the focuser, choose a middle one (as per weight) if you have more eyepieces. This is necessary so you can balance the telescope. Balancing is done by simply sliding the telescope tube inside the altitude bearing box. When you found an optimum balance point, you can fasten the telescope tube by drilling a 3 mm hole trough the bottom of the altitude bearing box and the tube, and drive in a 4x20 mm woodscrew.

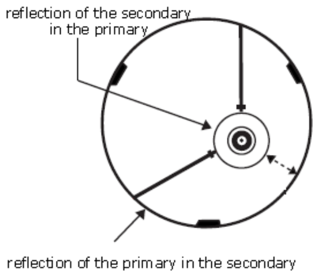
Collimation

Next step is collimating the telescope. A telescope is like a musical instrument. If badly tuned, it cant play nice music. If the optical axis of the mirrors are not adjusted, the image contrast and detail will suffer tremendously.
To do this, we need a collimation tool. There are many variations of this on the market, from simple sight tubes to holographic lasers, costing anything in-between 19$ and 200$. But you don't have to spend any money on it :)

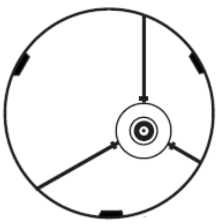
You can make a simple collimation tool in matter of minutes. Get a empty Kodak film canister, cut off the bottom, and drill a small hole (2 mm typically) in the lid center. What this tool does is to force you to place your eyeball at the center of the focuser if you wish to look inside....



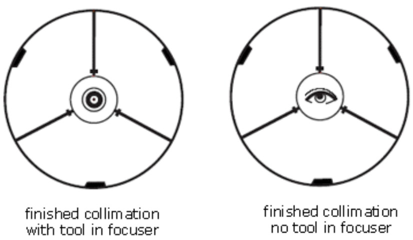
When you assemble your telescope, and take your first look trough the collimation tool, it will probably look something like this, a complete mess :)



What is what



Start with centering the secondary mirror under the focuser. You can adjust the distance relative to the primary mirror with the center bolt of the spider assembly, and the tilt with the 3 collimation bolts. The secondary holder can also be rotated around the center bolt if necessary. At this step, you wish to see the entire primary mirror reflected in the secondary. You will also see a black ring around the mirror , that is the mirror cell. The ring and the mirror should appear concentric. The small reflection (secondary in primary) is adjusted in the next step



Now we have to "put" the reflection of the secondary mirror in the center. This is done by adjusting the collimation bolts on the primary mirror cell. You will note how big your new telescope is because you can't reach the bolts and observe trough the focuser at the same time. So, do it in small steps, 1/4 turn, one bolt at the time, and check what happened. Slowly bring the reflection in the center. You now have a collimated telescope ready for first light!

Collimation can be compared to shoelaces. When you do this for the first time, you can spend as much as 10 minutes, and it looks so frustrating and impossible. But, with little practice, collimation is a 30 seconds process. Check your telescope collimation before every observing session, especially if it was transported a long way and bumped around.

The finished 150 mm Dobsonian telescope