How do you turn a chunk of glass into a telescope mirror, with a surface accurate to a couple millionths of a millimeter ?
And why do you wish to do so?

There are many reasons for grinding your own mirror. Either you want a unusual size, or focal length, or to satisfy your curiosity, or to have the "pride of achievement" by fabricating something as precise as a telescope mirror. You could also live in a part of the world where telescope optics are not commonly available, and this might be the only way to have a telescope.

Does it save money?
Well, that depends. Mostly on the mirror size you wish to grind, and the prices of the local market. In the US, telescope mirrors are the cheapest. A decent 6" (150 mm) mirror can be bought for under 100$. In Europe, prices are usually twice, if not three times that. In some countries telescope mirrors are unavailable, so they need to be imported, at high shipping, customs, and tax cost.
A 6" (150 mm) or 8" (200 mm) standard quality mirror will be cheaper if bought ready made. 250 mm (10") probably too.

Until you have purchased the blank, abrasives, polish, and pitch, your expenses are very near to a ready made mirror. The finished mirror needs to be aluminized, there are also shipping costs for this, and of course, your labor.
But, as the mirror size grows, prices go sky high. No mass production at these sizes anymore.. A 400 mm (16") mirror is practically impossible to find under 2000 € in Europe . Past the 12" (300 mm) size, grinding your own really pays off. Or, you want to make a super precise, highest quality mirror in the 150-200 mm size.

The only problem is, that a 400mm mirror is WAY too large to be your first time mirror project, and your beginner skill is not enough to produce a 1/20 wfe razor sharp planetary mirror.

Lets learn and practice first

A good starter size is the 150 mm (6") mirror. A 200mm (8") will also work.
Most ATM books and websites recommend a Pyrex® mirror blank, but in my opinion, annealed plate glass is better for this first, "learn and practice" mirror. It is cheaper, it is softer and grinds faster, needing less abrasives and with these small sizes, the low expansion glass like Pyrex has no practical (visible at the eyepiece) advantage.

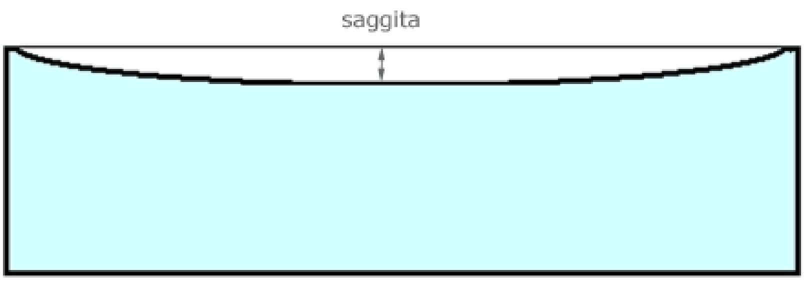
typical grinding kit

You might purchase a mirror grinding kit, and have everything you need included. If such a kit is unavailable, you need to do some scrounging. You can order a 19 mm thick disc at your local glass shop. Such glass is usually used for tabletops and window displays. A ship porthole will also do very nicely. You can use sandblasting abrasives, make your own polishing pitch. Or even silver the finished mirror if aluminizing is unavailable or too expensive.

Now you need to decide about the focal length of your future mirror.
If you are making this mirror to practice your skills for a future, large mirror you want to make, a fast, F4 - F5 mirror is probably your best choice. The future, large mirror will also be something like F4.5 so this is a good way to practice parabolising.

If you want to make a mirror that you will turn into your primary, visual use telescope, 1200 mm focal length would be recommended. That would make a 150 mm F8 , or a 200 mm F6 mirror.

First phase : rough grinding (or hogging out)



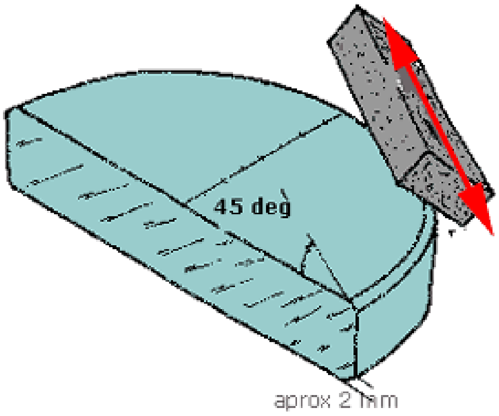
In this stage of grinding we want to dig out the flat glass blank, in other words, create a saggita.
Saggita is a section of a sphere, its radius of curvature (ROC) is TWICE as long as the focal length of the mirror. Example : a mirror with a 2000 mm ROC will have 1000 mm FL.

"Depth table"

	150 mm mirror	**200 mm mirror**
FL= 1200 mm	1.17 mm	2.07 mm
FL= 1000 mm	1.4 mm	2.5 mm
FL= 910 mm	1.55 mm	2.75 mm
FL= 750 mm	1.87 mm	3.33 mm

As you can see from the table, the "faster" the telescope (shorter focal ratio) a deeper curve is needed.
This of course means that more glass need to be removed, which takes more time and effort. And, parabolising such a fast telescope becomes more difficult. The 200 mm , 750 mm focal lenght mirror shown in this table is a bit of a extreme for visual use,... but it might be very good for astrophotography.

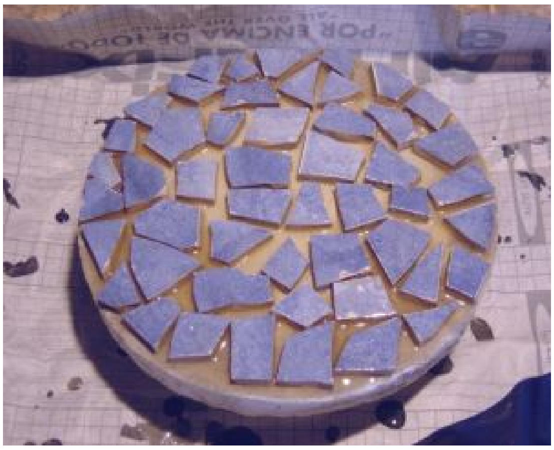
To start hogging out, we need the glass disc, rough grit (#80 typically) and a tool.
But, before any grinding , the glass disc must be beveled.



The bevel is needed to prevent chipping of the disc edge while grinding. Use a tool sharpening stone, wet it with water, and grind at 45 degrees, around the disc, (red arrow) . A 2 mm bevel is enough

Making a tile tool

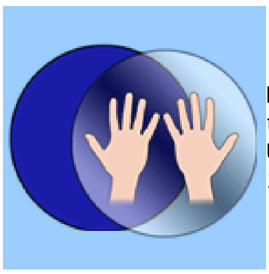
"In the old days" it was usual that a mirror kit is delivered with 2 glass blanks.
One as the mirror, and the other as the tool. If you have such a kit, save the second glass, and make a tile tool.
Tile tools grind faster, and you can make 2 mirrors instead of one.
Or you can share the costs of a mirror kit with a friend and make a mirror each.



A tile tool is a disc poured from cement, with a layer of hard, porcelain tiles epoxied on it. Make it the same size as the mirror in diameter, 50 mm thickness is fine. Also, it is important to impregnate it. "Painting" the whole tool with epoxy or boat varnish will be just fine. On all the ATM webpage's and books you will see neat, equally sized, equally spaced tiles.

The key to successful mirror grinding is randomness in stroke numbers and tool and disc rotation. Adding more randomness with a tile tool made from tiles that have been smashed with a hammer cant do any harm :)

Always work wet! Sprinkle some water on the grit before you start grinding!
Glass dust is very dangerous and can cause silicosis, a serious lung disease if inhaled!

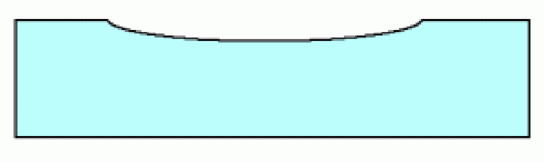


For hogging out, we start with the "chordal stroke" Put the tool on the bottom, add half a teaspoon of #80 grit, sprinkle with water and place the mirror center near the edge of the tool. Use 1/3 mirror diameter strokes. This means that stroke is 1/3 length **in total** , 1/6 forward, 1/6th backwards. For a 150 mm mirror, 25 mm forward, 25 mm back.

It is important that the mirror is suspended. A piece of old carpet, a old towel, or a stack of old, wet newspapers will be just fine. This will prevent astigmatism due to uneven support of the glass disc...

To get a sphere segment in the glass disc, we need to rotate both the mirror and the tool. As randomly as we can. Example : Make 6 strokes, rotate the mirror 40 degrees clockwise, and the tool 30 degrees counterclockwise. Make 7 more strokes, rotate the mirror 60 degrees clockwise, and the tool 20 degrees clockwise. Don't think in degrees, nor numbers, just spin it **randomly.**

Rough grit breaks up quite fast, You will know that the grit is used up when the loud , crushing grinding noise disappears. Add more grit, spray with water and continue. Rotate rotate rotate! Slowly.. you will see the first indentation starting to appear in the glass disc center... To see it and measure it, you need to rinse your mirror, and the tool from time to time. Prepare a bucket with water, and rinse your glass disc there. Do not rinse it in a sink or similar, because you will be calling the plumber very soon. The used grit and glass mud settles on the pipes like cement.



After a while of grinding with the chordal stroke, you will notice that the disc has developed a depression in the center, but the edges have not, or have hardly been touched. Measure your saggita, either with a spherometer if you have one, or put a straight edge over the mirror center and use feeler gauges.

It is the same thing as the chordal stroke, only now you don't grind with the mirror center over the tool edge, go over the center. Again, rotate randomly, both tool and mirror. As soon as the curve has reached the edge, and your saggita is equal or slightly deeper (depending on method you use later) you can go on with the **fine grinding.**

There are 2 ways to proceed. You can slowly reduce your overhang, and convert to the 1/3 center over center stroke, then alternate the "tool on top" (TOT) and "mirror on top" (MOT) to maintain the saggita depth. When MOT , the curve becomes deeper, with TOT it becomes shallower.

My favorite method is to grind with the chordal stroke a bit deeper (0.2-0.3 mm on this mirror size) than the target saggita , then use TOT until end of grinding.
This saves a lot of grit! As you might noticed by now, much of the grit is wasted as it falls in the space between the tiles. Only the depth matters, the edges will get grinded quickly as soon as you turn the tool on top and grind a with 1/3 center over center strokes.

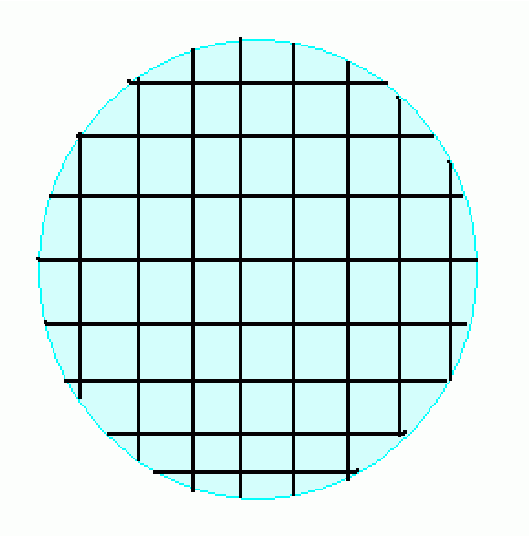
But first, there is a major cleaning operation ahead :) Close your #80 grit container and put it away. In short, you need to clean and dispose of every LAST grain of #80 grit from your mirror, your tool, your rinsing bucket, your mirror support, and yourself.
Pour off the water from your rinsing bucket in the drain, but leave the settled mud. It is very inert, its practically the same as sand. You can throw it away in your garden, no problem.

Clean the bucket thoroughly. Use a brush and scrub the channels on your tile tool. Clean everything, including your spray bottle. One, single grain of #80 grit can cause a bad scratch once you move on to finer grit. Also, take a shower, change your clothes, and clean your fingernails before you continue with finer grits.

Fine grinding

After we have hogged out the saggita, we use smaller and smaller abrasives to remove all the remaining pits from rough grinding and prepare the glass disc for polishing and figuring. A typical grit sequence can look like this : #120, #220, #400, #800, #1000, and one finer grade, if available. Grind with 1/3 center over center strokes. Measure the saggita, but don't be worried if the mirror is not exactly a F8 or a F6. To perform well, the precision of the optical surface is important, and the mirror being a F6.2 or 7,9 is completely insignificant. You will make your own custom fit tube for this telescope anyway :)

As we have thoroughly cleaned all the tools and working space, we can start with 120 grit. After a wet or two, this is a good time to test the sphere on the mirror. The test is very simple



Rinse and wipe the mirror dry. Draw a grid on the mirror surface with a permanent marker (<--picture)
Add the usual half teaspoon of grit, sprinkle with water and grind for a couple of minutes, rotating tool and mirror often. Rinse the mirror and inspect the grid lines. If the grid is worn out evenly, you are doing fine. If you grinded with TOT, the edges will be more worn than the center, and vice versa if MOT. This is okay. Any other irregularities indicate that there is something wrong either with your strokes, your tool or mirror support. Also, check your bevel! Fix if necessary. Take a magnifier, or a 25 mm eyepiece (use reversed) to inspect the surface. When all the pits look uniform, and there are no remaining pits from previous grit sizes, you can switch to finer grit. Check the edge, and the center, these are the places most likely to "hide" pits. Take your time, and remove all the remaining pits.

Mirror surface after #220 grit

There is not really much to say about fine grinding. You will notice that the grits last longer and longer, as smaller in size. Grinding noise becomes more and more silent. Perform the grid test once per grit size. Clean thoroughly after going to finer grit. Past#400, the focal length will not change (significantly) anymore, and the glass becomes very smooth, even shiny if observed at a low angle. It starts to look like a telescope mirror :)

The #400 grit is the finest size you will add with the teaspoon. Finer than that, they need to be premixed with water.
Take a plastic bottle (from drinks etc) 0.5 liters, add a few spoons of grit in the bottle and add 6-8 times the volume of water. Shake well before pouring the grit on the mirror. It settles back in just a few minutes. Also, you can add a drop of glycerin into the mixture, this will prevent tool and mirror getting stuck, something that happens quite often at very fine grit sizes....