Parametric Design

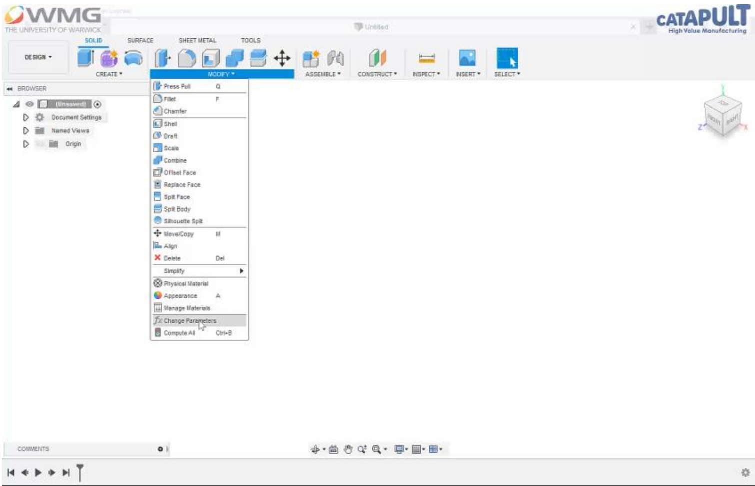
Ball Bearing

Let’s design a ball bearing that can be easily changed without having to re-draw the entire design. This is really useful for 3D printed parts where we might need to make a few versions before getting things just right.

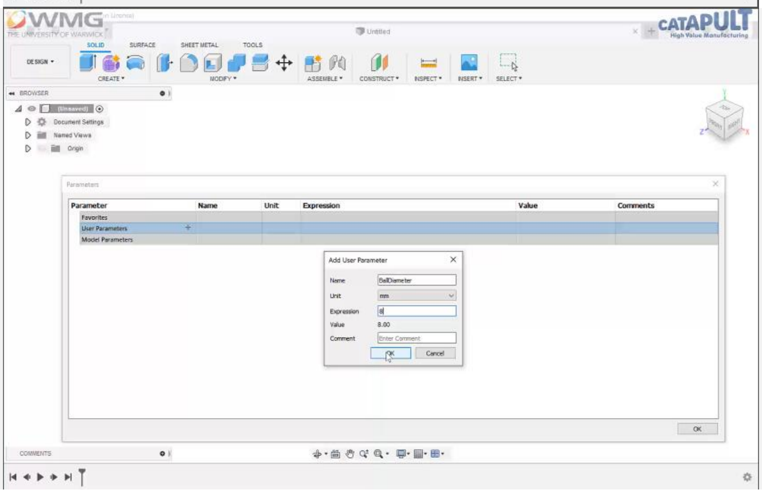
We will be using parameters and constraints a lot in this design.

Open Fusion, get stuck in, and let us know any questions at wmgoutreach@warwick.ac.uk

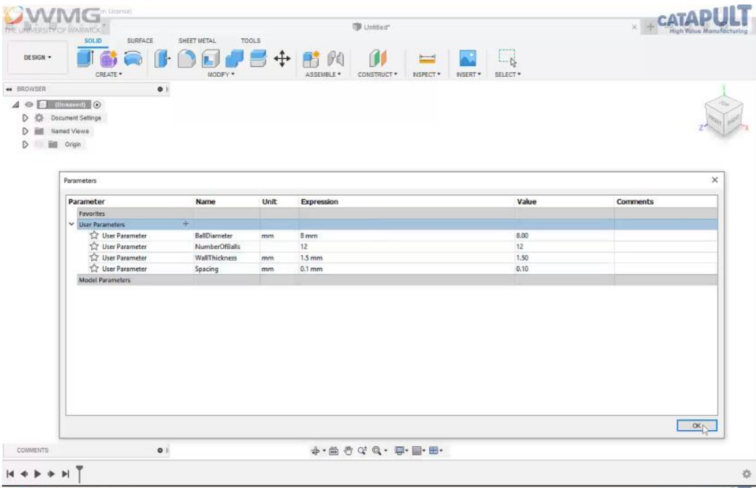
1. Modify > Change Parameters



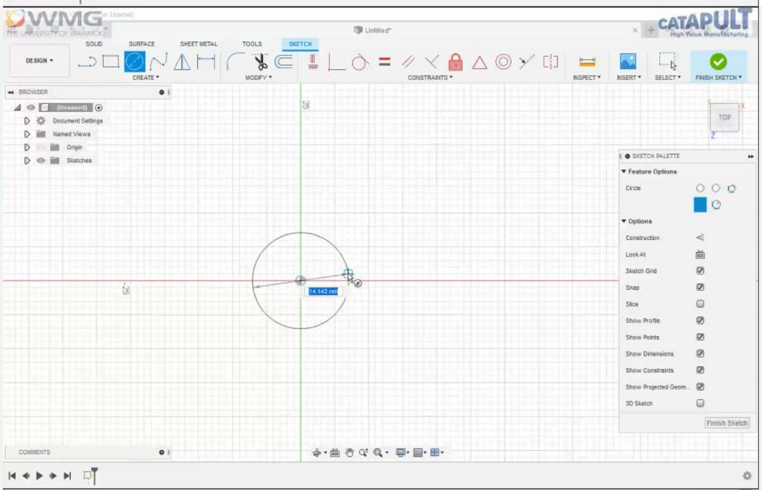
2. Click ‘+’ under user parameters and make
   a. BallDiameter = 8 mm



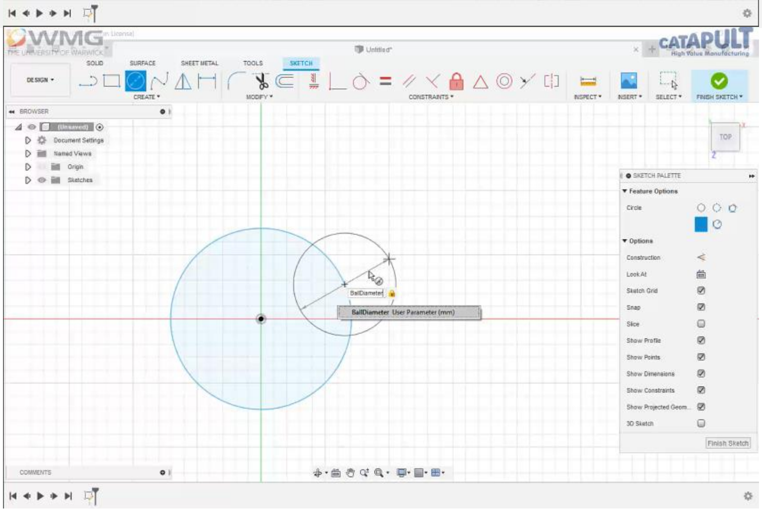
b. NumberOfBalls = 12 (no units)
c. WallThickness = 1.5 mm
d. Spacing = 0.1 mm



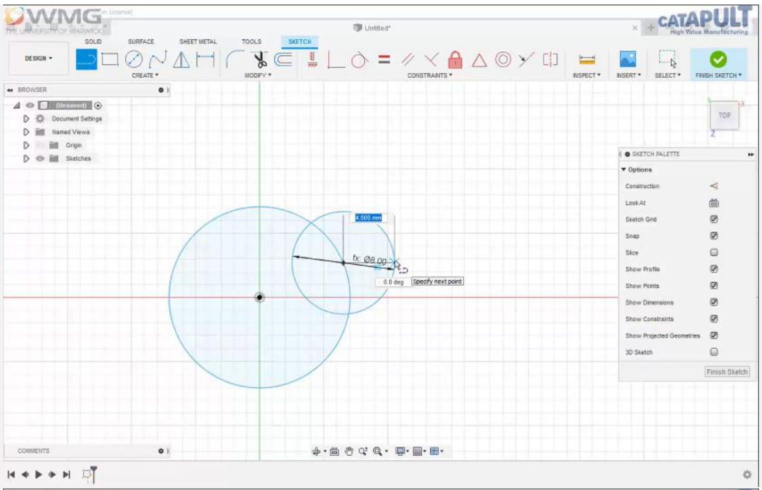
3. Start a sketch
4. Draw a large circle – no dimensions – this will be the track the balls roll around. The size of this circle doesn't matter.



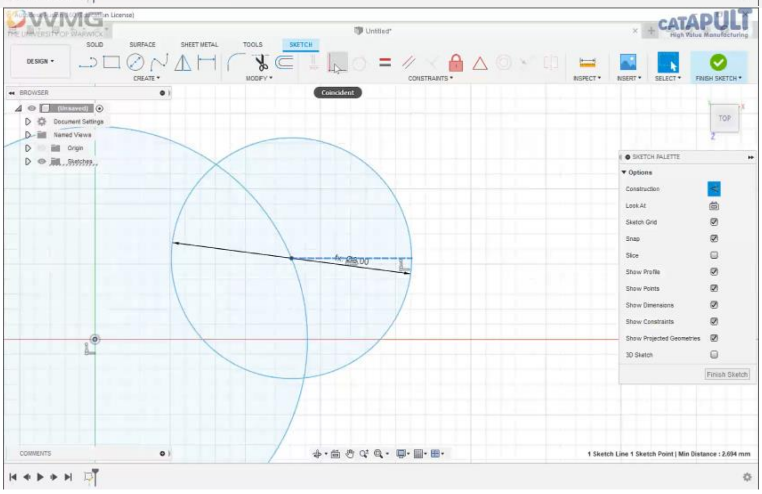
5. Draw a small circle – BallDiameter – this will be the ball around which the rest of the design is based



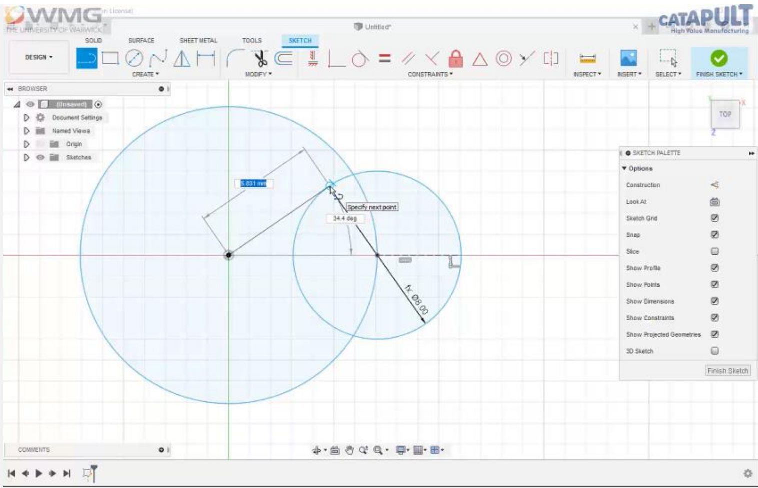
6. Draw a radial line from the centre of the ball to the perimeter of the ball that is horizontal. This will help us align things later.



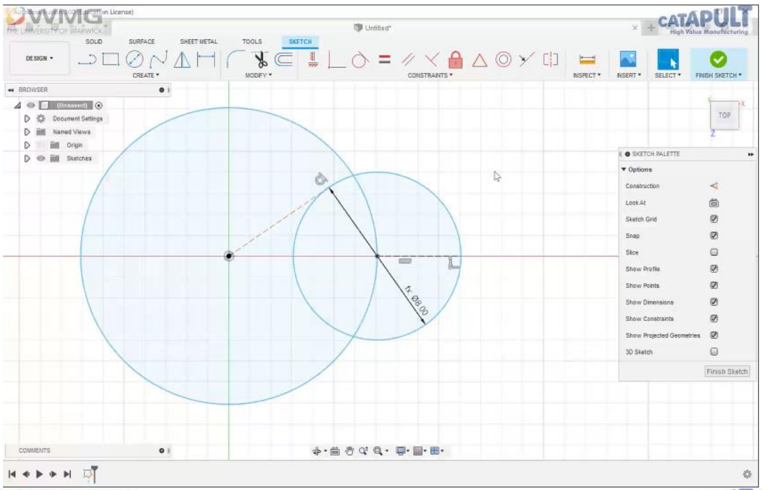
7. Align the ball outline on the roll track – click the centre of the large circle and the line you've just drawn while holding shift. In Sketch > Constraints click 'Coincident' which has a red line vertical, a black line horizontal and they meet at a right angle with a red square.



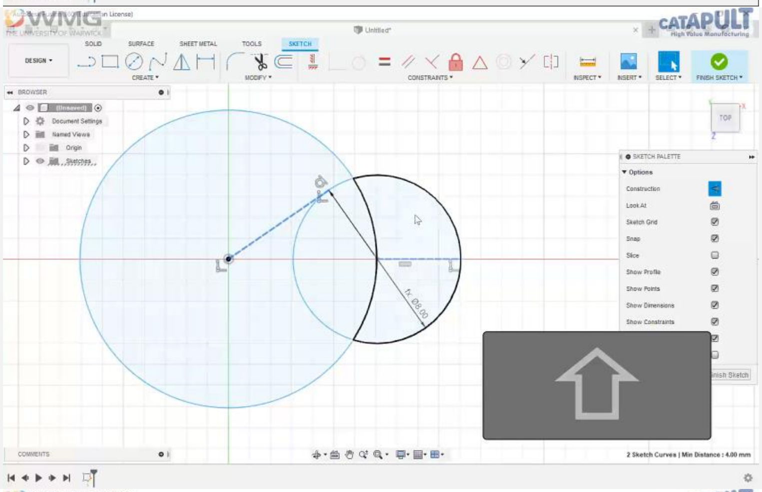
8. Draw a line from the centre of the large roll track circle to the edge of the ball outline – making sure that it is tangential to the ball outline. If you can't get it to snap there you can draw it anywhere and then select the tangent constraint and select the circle.



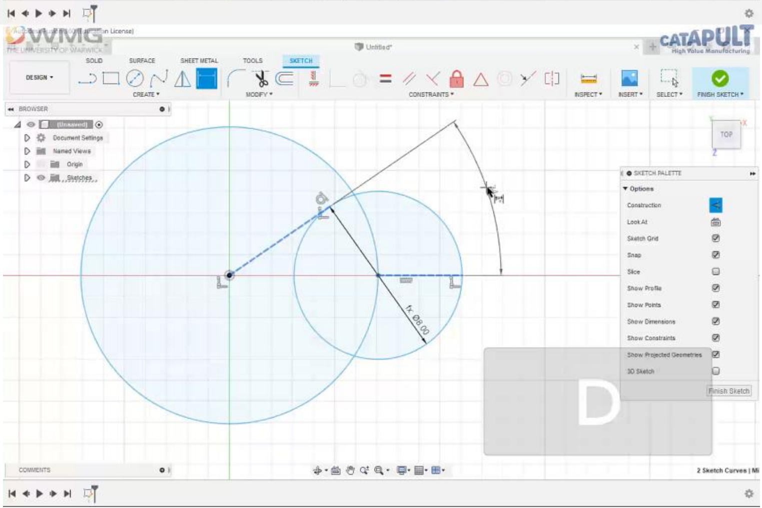
9. We aren't going to build anything from this tangent line or the radial line you drew in step 5. What we can do is make these construction lines so that we don't get confused. Select the lines and then press 'x' on the keyboard. They should now appear dashed.



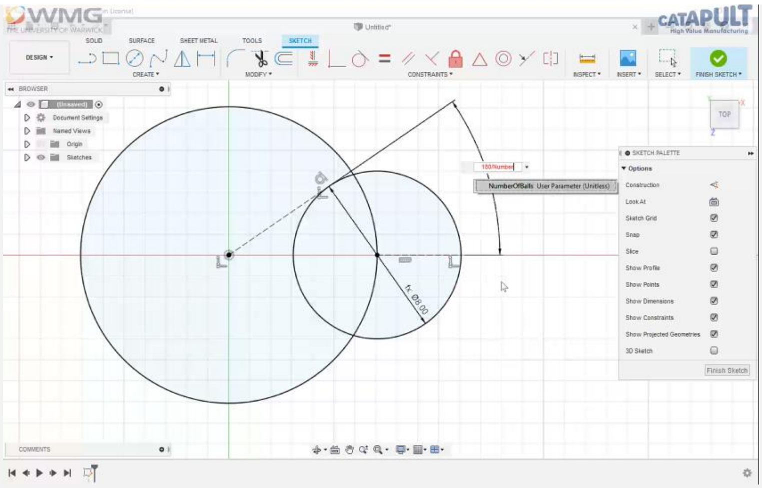
10. The size of the roller track is based on the diameter of the balls and the number of balls present. The tangential line will help us maintain this. Select it and the radial line inside the ball circle.



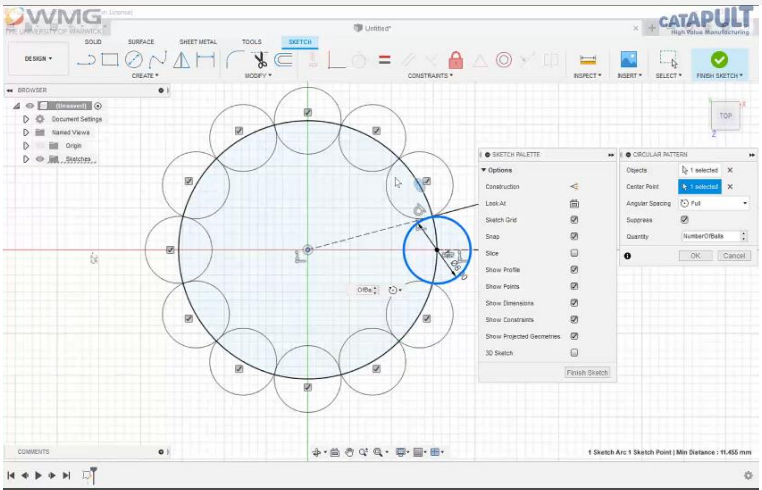
11. We need to constrain the angle between them so press 'd' on the keyboard or the sketch dimension button in Sketch – it looks like two vertical lines with a blue double headed arrow in between. You should now have an angle being displayed.



12. This needs to change as the number of balls changes so we will need to link the angle to the number of balls. The angle we are defining is the angle between the tangent of the ball and the centre of it – which is half of the circle. This means the equation will be angle = 360 / number of balls*2 or simpler, 180/NumberOfBalls. You should see the size of the roller track adjust to make enough space for the balls.



13. Test the paramerisation out here by selecting Create > Circular Pattern and Selecting the ball circle for ‘objects’, the centre of the roller track for ‘centre point’ and the quantity should be ‘NumberOfBalls’

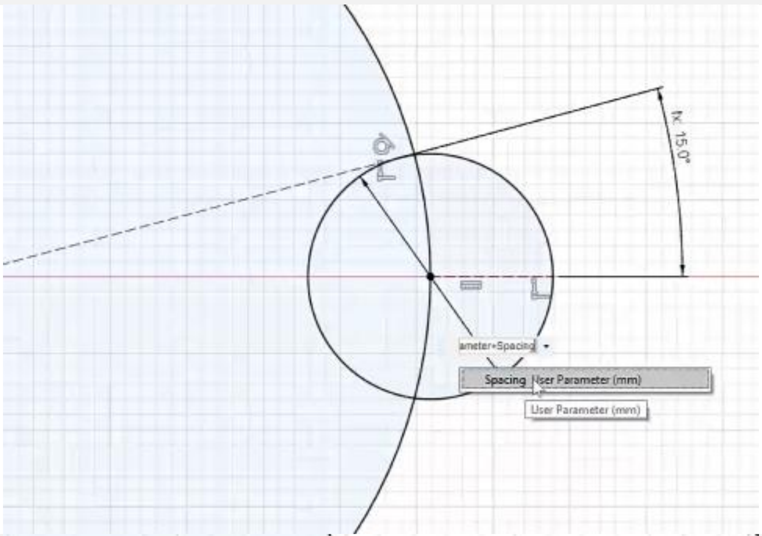


Optional – change the number of balls by going to Modify > Change Parameters and changing NumberOfBalls to see if the parameters change correctly to get a series of balls going around the roller track.

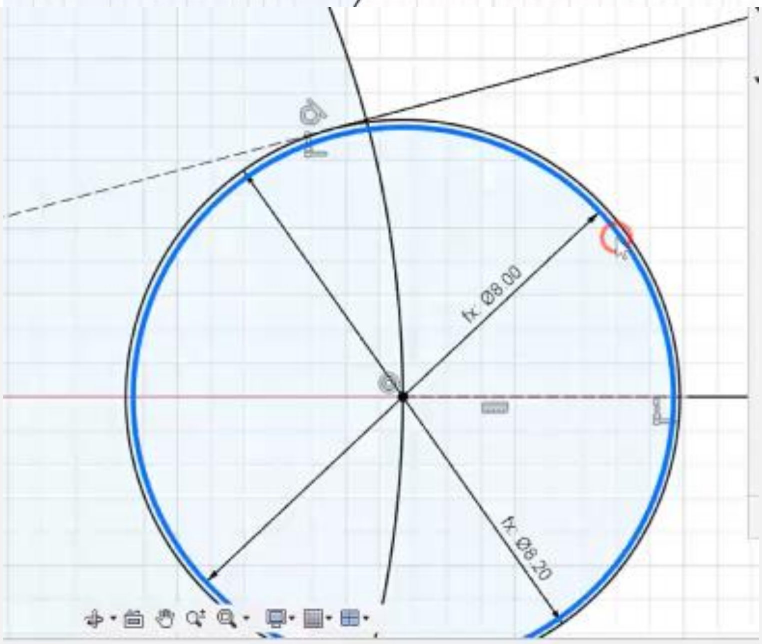
14. The issue is that these balls are all in contact so might jam up when we try to print it. We need to add in the ‘spacing’ around each one. We don’t need to see the circular pattern, it was only useful to show us that the parameters we working. We can hit

undo until it goes back to just one circle.

15. Double click on the diameter dimension of the ball circle and change it from ‘BallDiameter’ to ‘BallDiameter + Spacing*2’ It has to be *2 because we need space on both sides of the ball.

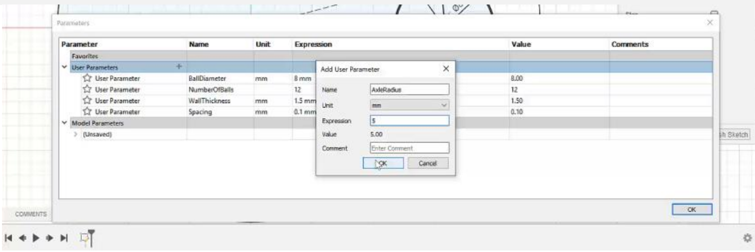


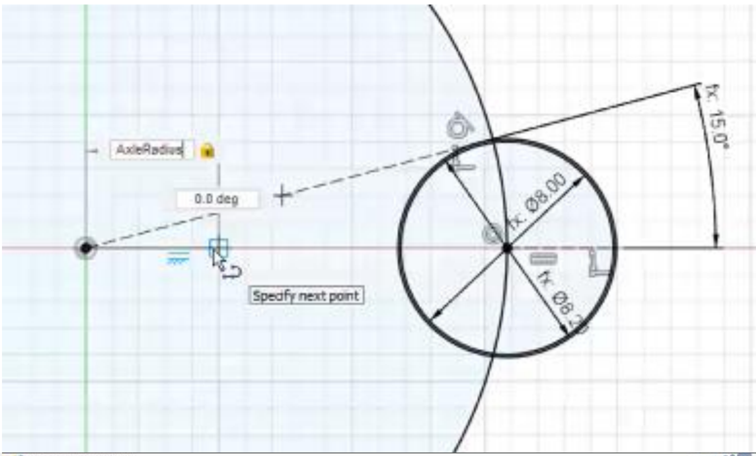
16. This slightly larger circle is now the space that has to be left for the ball bearing in the roll track for it to move around in. If we test this print out and there is too much play in the bearing then we can reduce the ‘Spacing’ value, or if the whole thing jams up we can increase it.



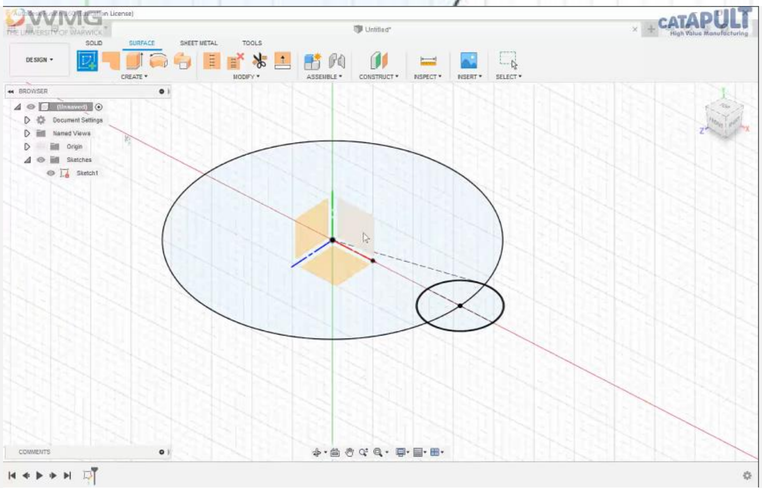
Optional – if it helps to picture it, you can also draw a circle inside the first one that has a diameter or ‘BallDiameter’ so you can see the size of the ball as it will be printed and the gap that will be left for it.

17. Finally for this sketch add in a line from the very centre of the sketch and make the length of it ‘AxleRadius’ – you’ll have to make a new parameter. Finish the sketch.

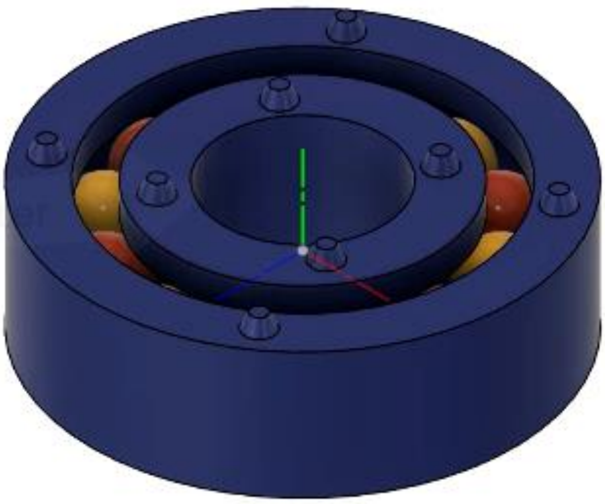


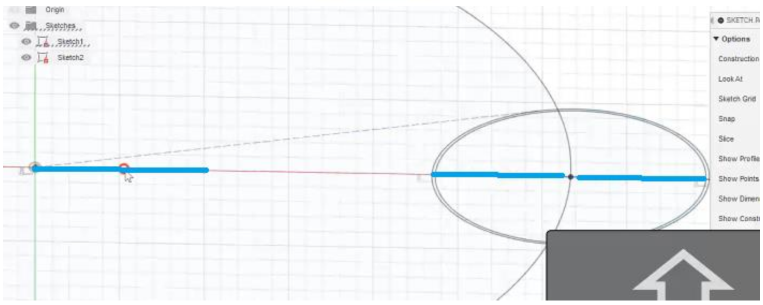


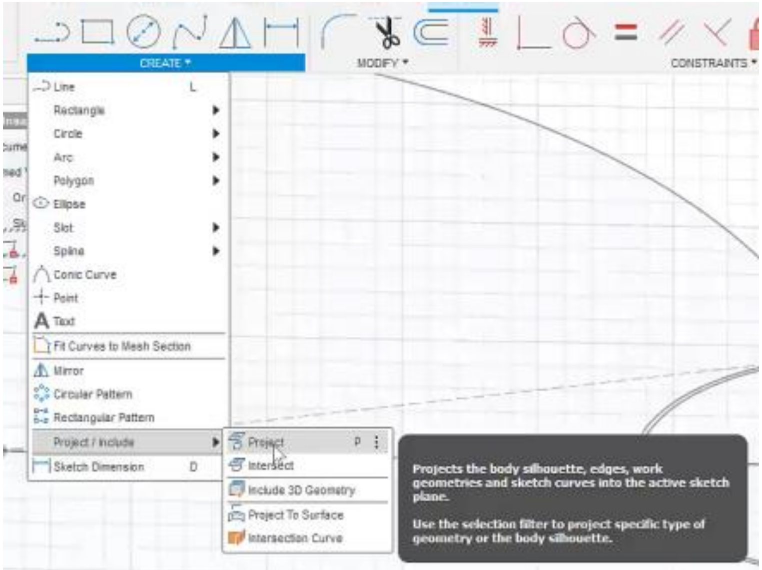
18. Create a new sketch in the plane that contains the centres of both circles.



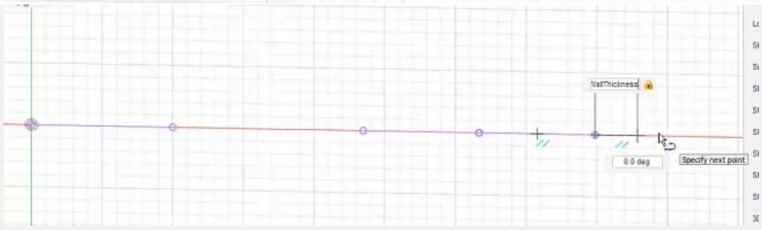
19. We need to draw the two sections of the bearing now. An inner and an outer ring will hold the balls in place and stop them coming loose. The inner and outer rings must not be connected so that they can spin separately to each other. All the sizes and positions from the first sketch must be applied to this one too so we can select Create > Project/Include and then select the three horizontal construction lines from Sketch1 – the AxleRadius line and the horizontal lines inside the Ball Circle.



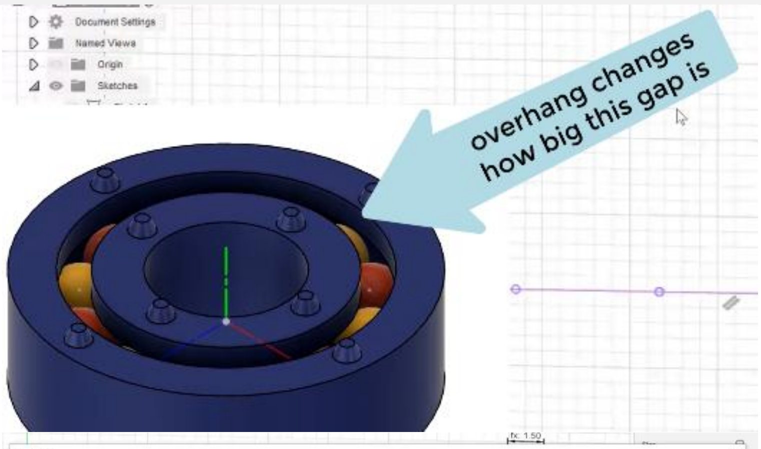


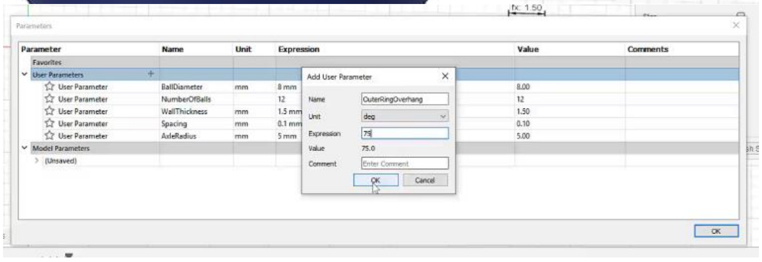


20. Draw a new line in Sketch 2 from the end of the outer projected (purple) line (the one that is furthest from the origin) out away from the centre of your whole drawing with the length 'WallThickness'



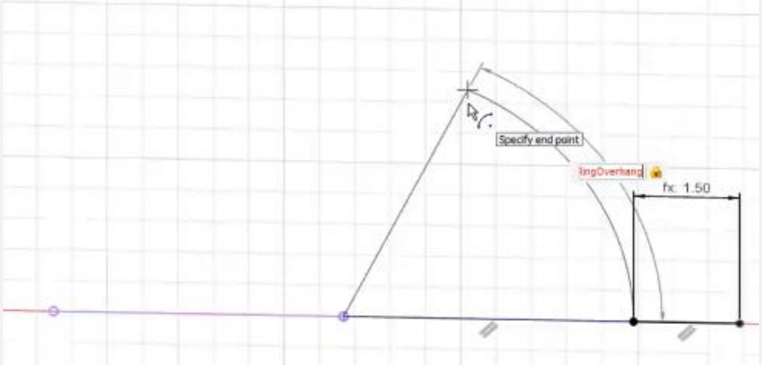
21. We need to draw some arcs to make the shape for the roller track. The outer ring can be symmetrical with the same amount of overhang on the top and the bottom. We can define an angle for this in the Parameters list in case we want to change this later.



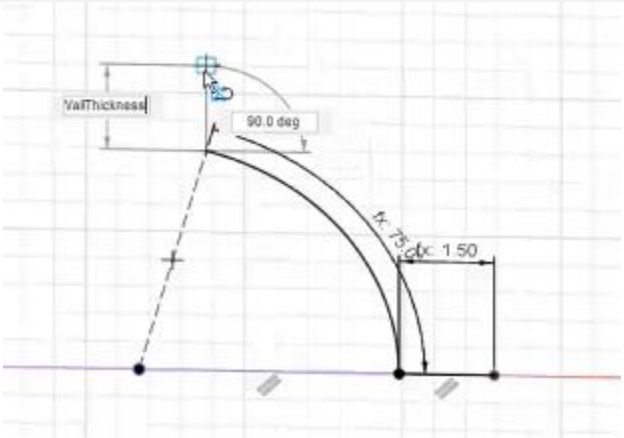


22. The more overhang we have the less likely everything is to jam up against each other. The less overhang we have the more play we will end up with in the bearing and the balls might even just fall out. Select Create > Arc > Centre point arc.

    The centre of the ball circle is the centre of the arc, set the radius by clicking on the end of the first line you drew and set the angle as 'OuterRingOverhang' from the parameters list.

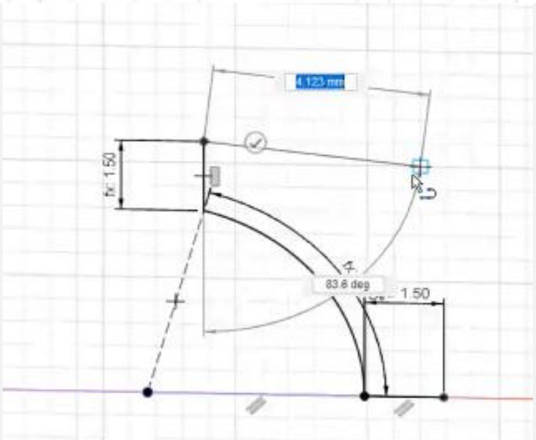


23. Draw a line vertically upwards from the end of your new arc with a length 'WallThickness'

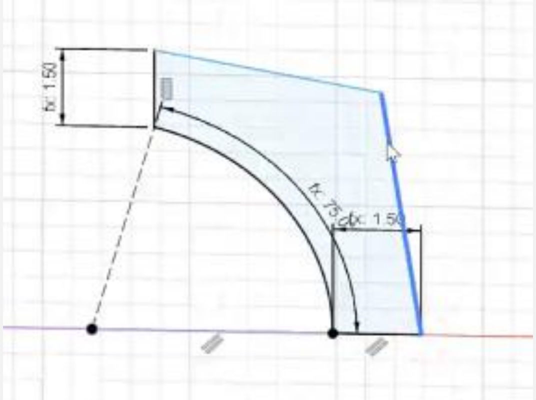


24. To complete the outer ring we need to draw two more sides, constrain them and then mirror the top half.

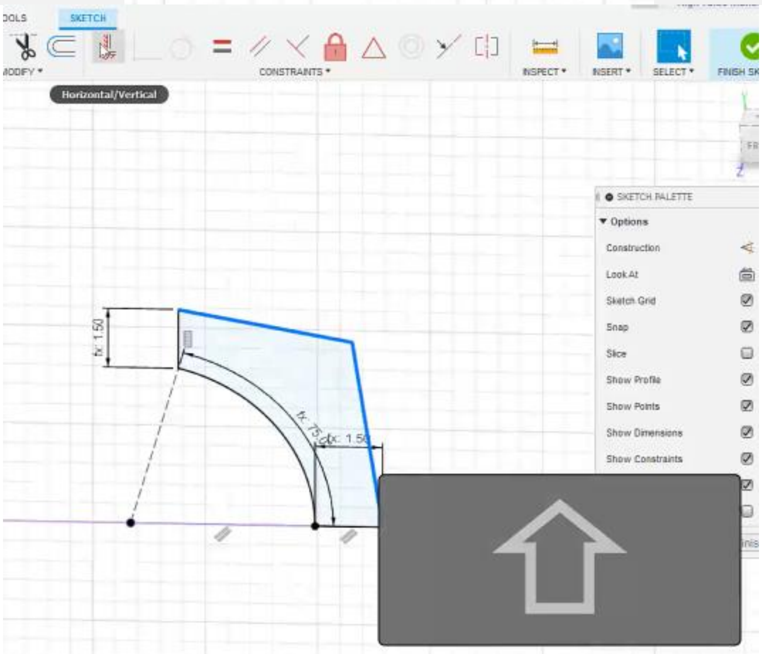
    Draw a line from the vertical line you just drew with WallThickness as its length and take it somewhere to the right. We will constrain it shortly.



Draw a line from the end of the last line you drew and take it down to the end of the horizontal line that is on the red axis (as shown) to complete this shape.



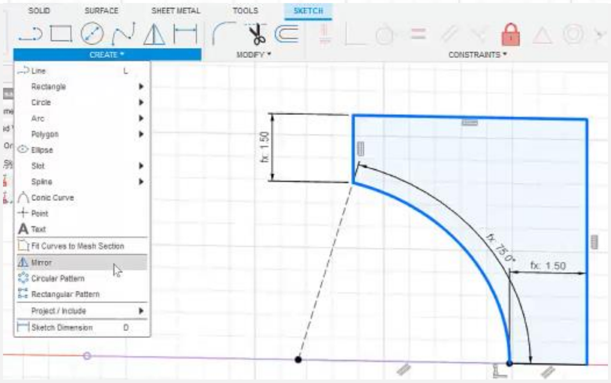
25. Constrain these two new lines by selecting the 'Vertical/Horizontal' Constraint that looks like two black lines close to each other with red hatching either on the left or underneath the black lines.

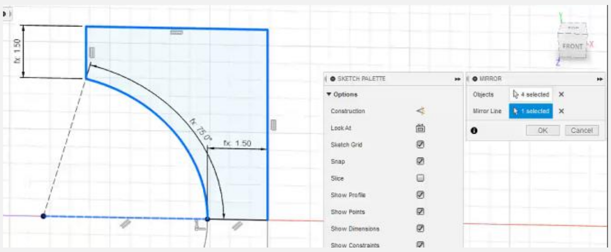


26. Select all the lines except the horizontal short one you drew in step 18 and select Create > Mirror.

Select the horizontal construction line you projected into this sketch from sketch 1 as the mirror plane.

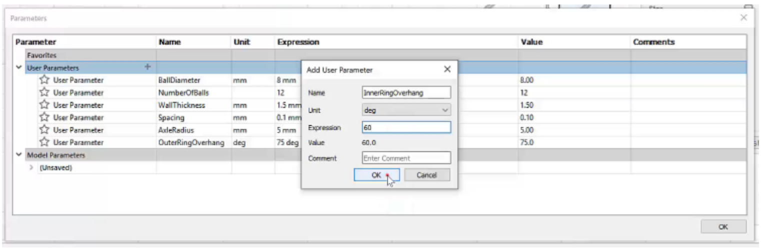
It's good to use a construction line for your mirror plane because you're unlikely to change your construction lines later.



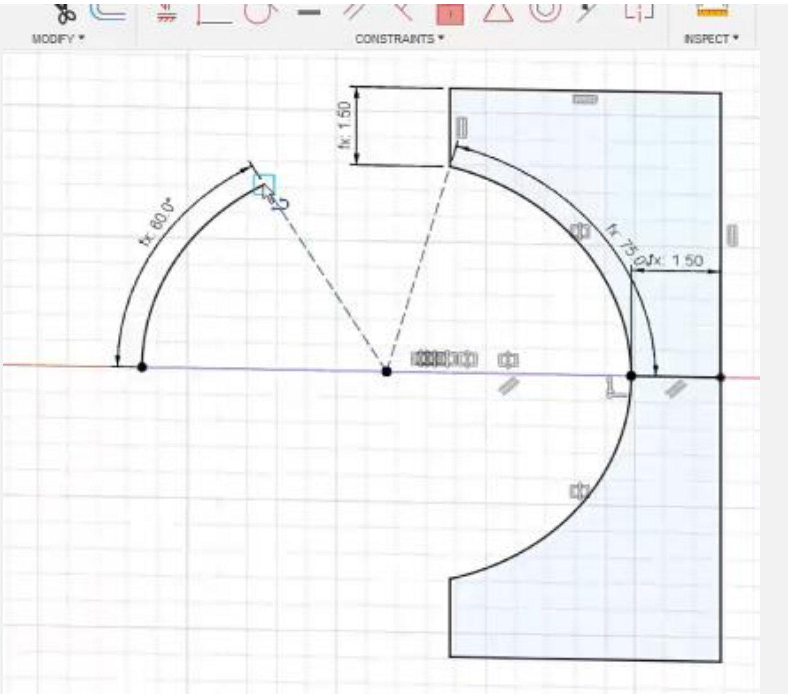


27. The inner ring is slightly more complicated because we need to make sure that we can get to the inside a little bit in case we need to do any post-processing to get everything rolling.

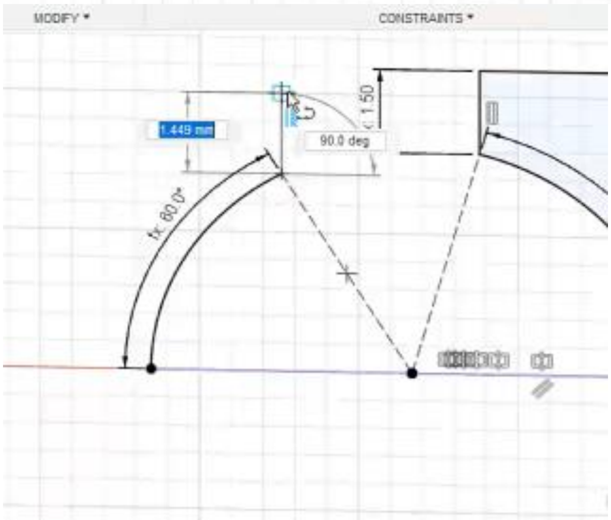
    Make a new parameter called InnerRingOverhang with a value of 60 degrees. We want the overhang angle to make the upper side of the track.



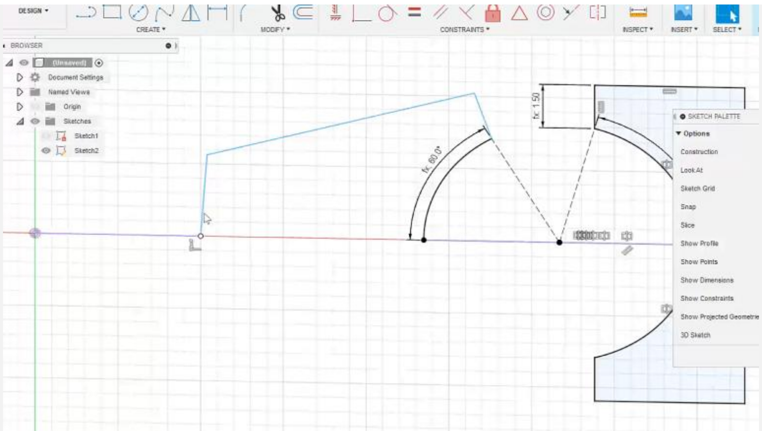
28. Draw a centre point arc with the centre point as the centre of the circle, the first point as the end of the purple construction line you projected that goes left from the centre of that circle. Take it upwards and set the angle as InnerRingOverhang



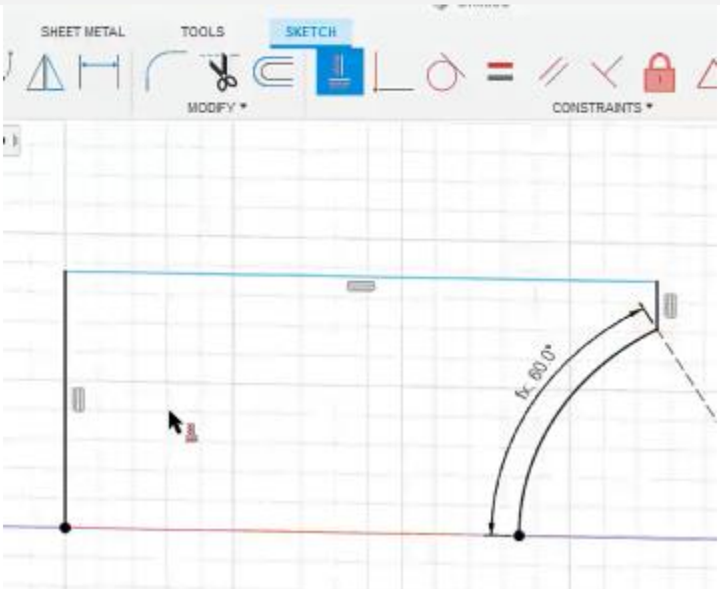
29. Draw a vertical line up from the end of the arc.



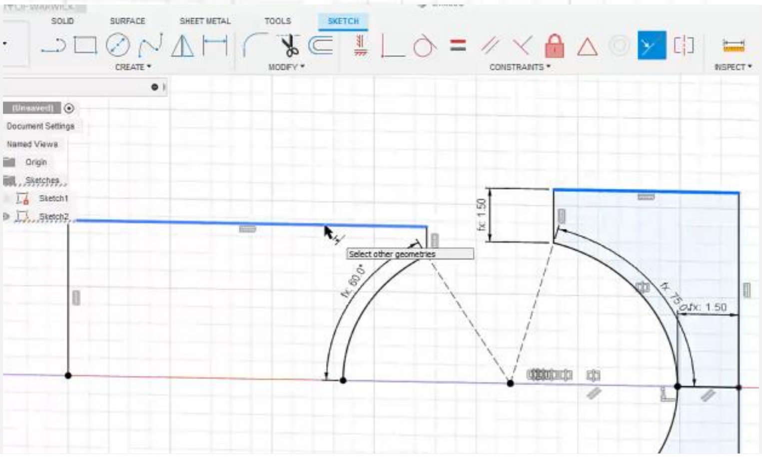
30. Draw two more lines. One for the top edge of the inner ring and the other should be the wall that will eventually be the hole for the axle.



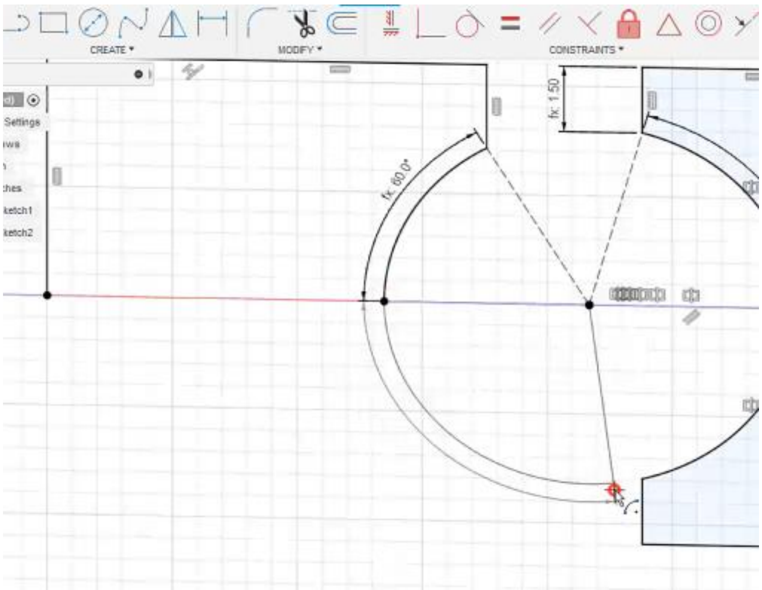
31. We will use the horizontal/vertical constraints again to make these lines neat.



32. Line up the top edge of the inner bearing case with the top edge of the outer bearing case. Select the colinear constraint

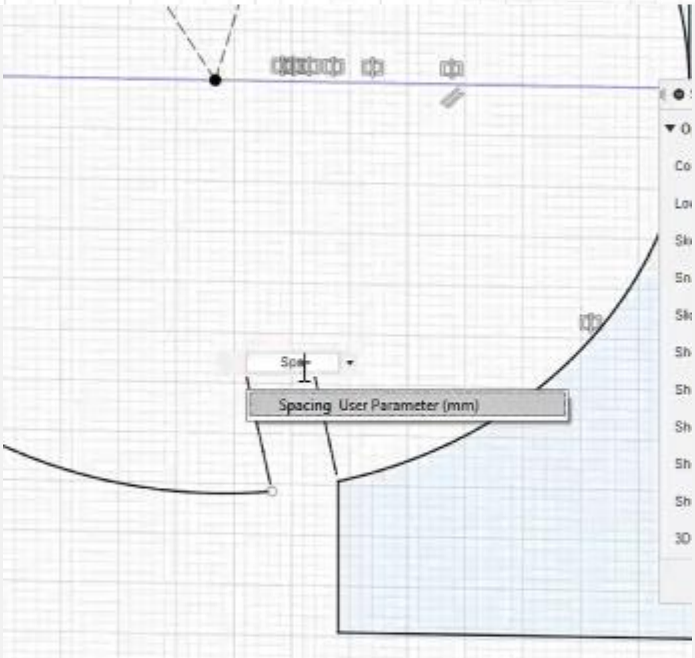


33. Draw a new arc with its centre point in the middle of the circle, its first point as the left end of the purple projected construction line and the final point somewhere near the edge of the outer casing. We will define the end of this point with a constraint next.

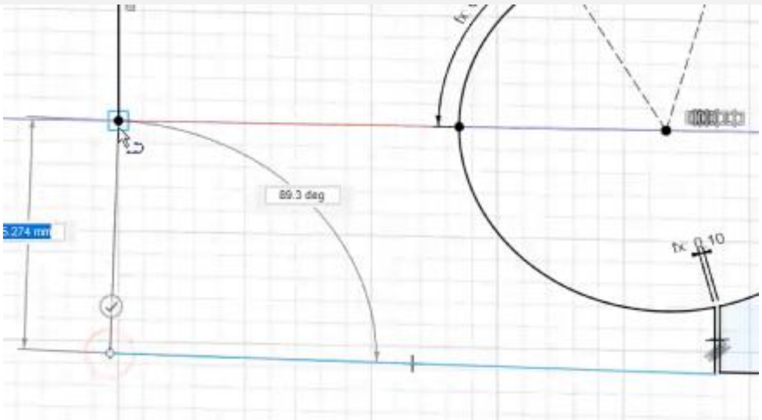


34. Press “d” or click add sketch dimension to add a constraint to the end of the arc you’ve just drawn.

    Select the end of the arc and the corner of the outer bearing case and drag the resulting dimension up and to the left – we don’t want to have this dimension going vertically upwards (that means we would only be constraining the horizontal distance between these points). Set the distance between these points as the Spacing parameter.

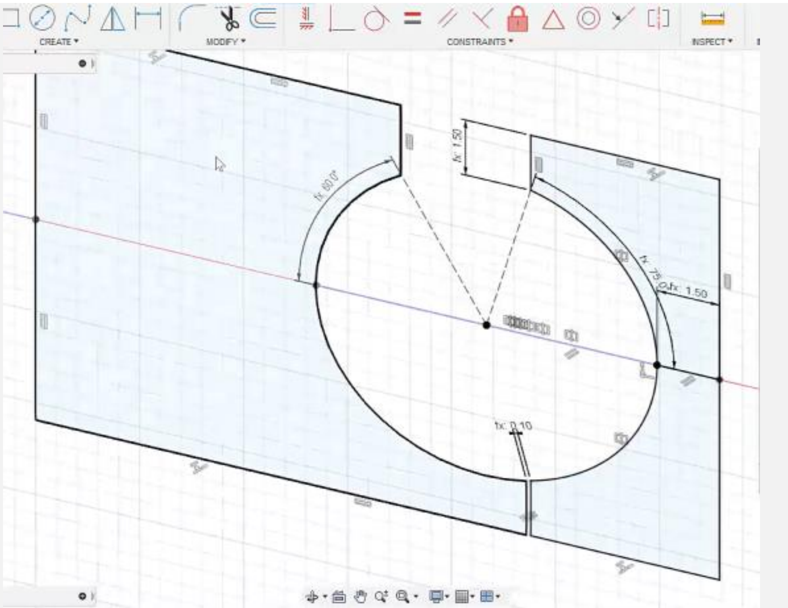


35. Draw in the rest of the walls of the inner bearing case exactly as we have for the rest of the bearing.

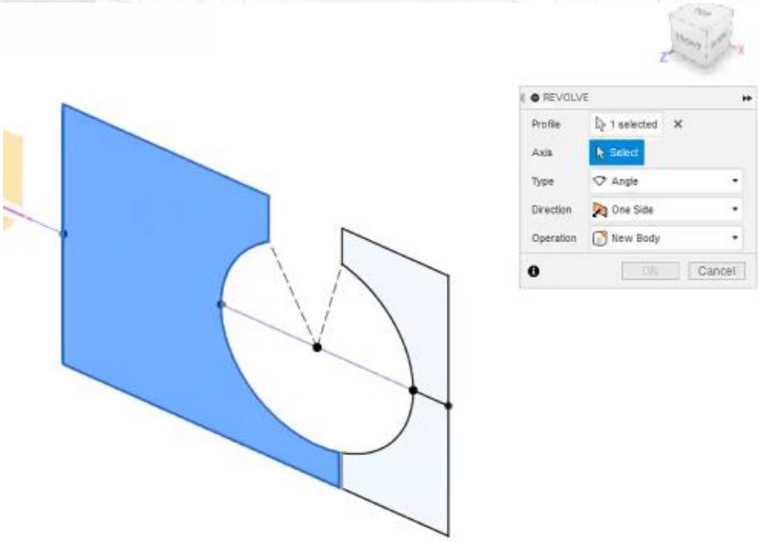


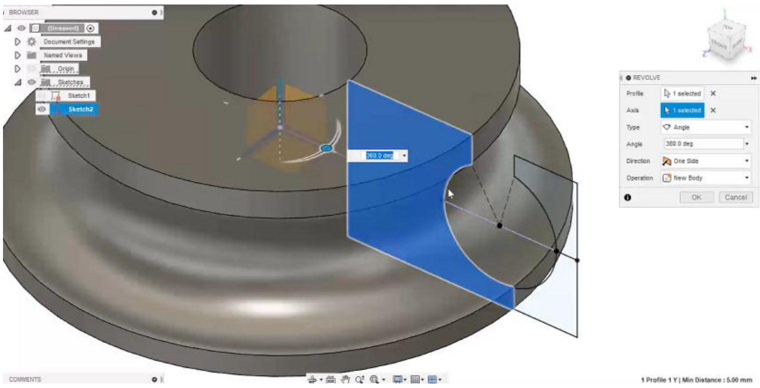
36. Use the vertical/horizontal constraints on the lines you've just drawn and then line up the bottom edges of the inner and outer casings with the collinear constraint.

    Finish the sketch.

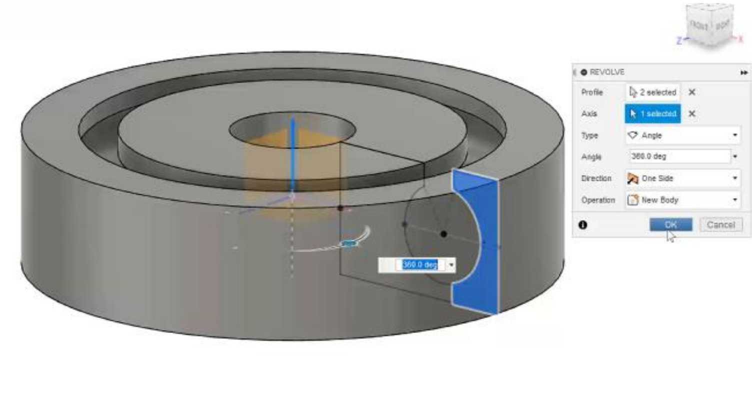


37. Select the Revolve tool. Make the Origin visible and select the vertical axis.

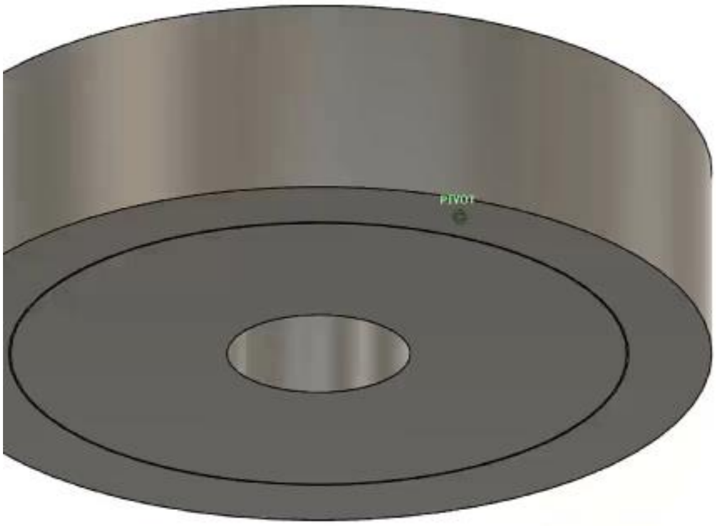




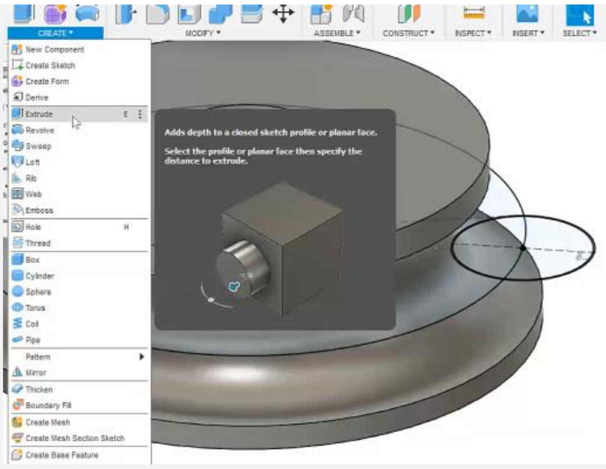
38. Make your sketch visible again and then repeat for the outer ring.

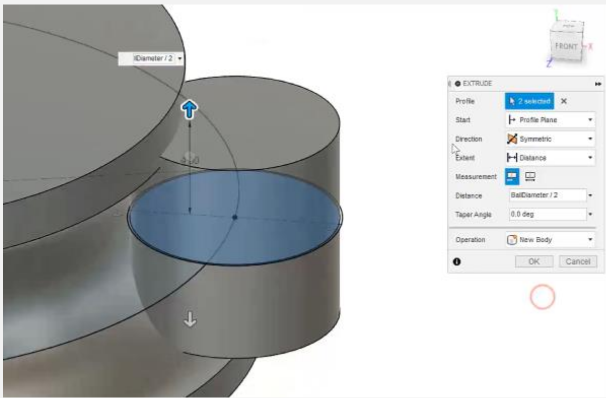


39. Move the camera underneath to check on the size of the gap.



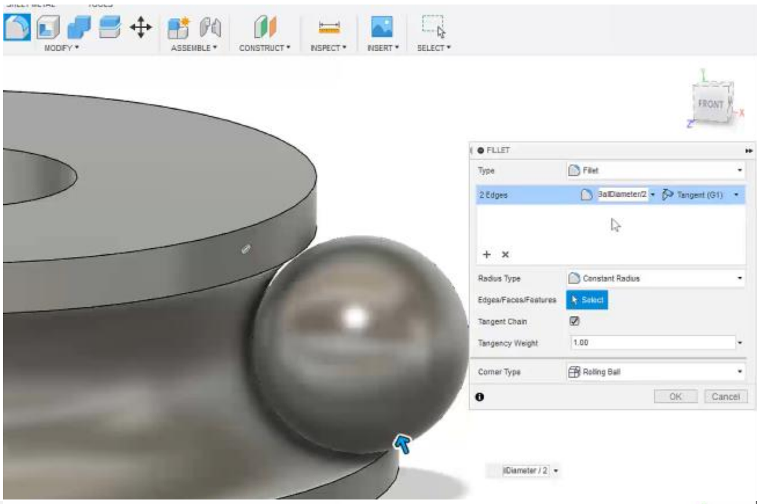
40. Now we need to make the balls to sit in the roller track. Unfortunately we can’t use the sphere tool because the centre of it can’t be parameterised so won’t change as we need it to. Instead we will improvise and make our own sphere too using the sketch. Go back to your first sketch and extrude the BallDiameter circle using ‘symmetric’ and BallDiameter/2. Make sure to select ‘New Body’



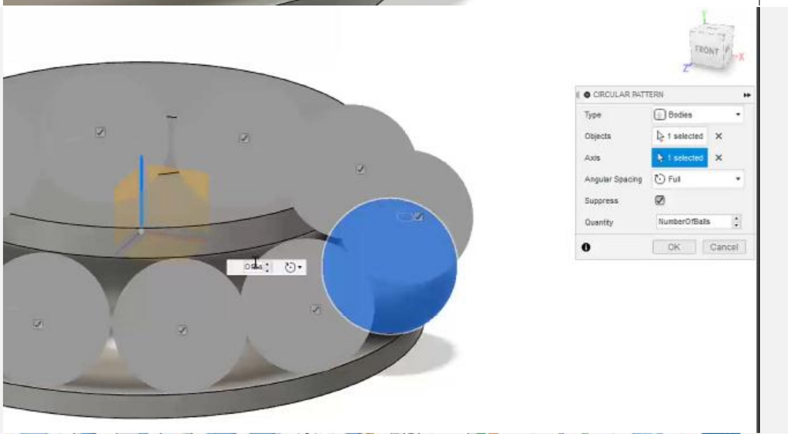


41. Click Modify > Fillet and then select the top and bottom edges of the cylinder. Set the fillet distance to be BallDiameter/2 – improvised sphere! This will move with the parameters.

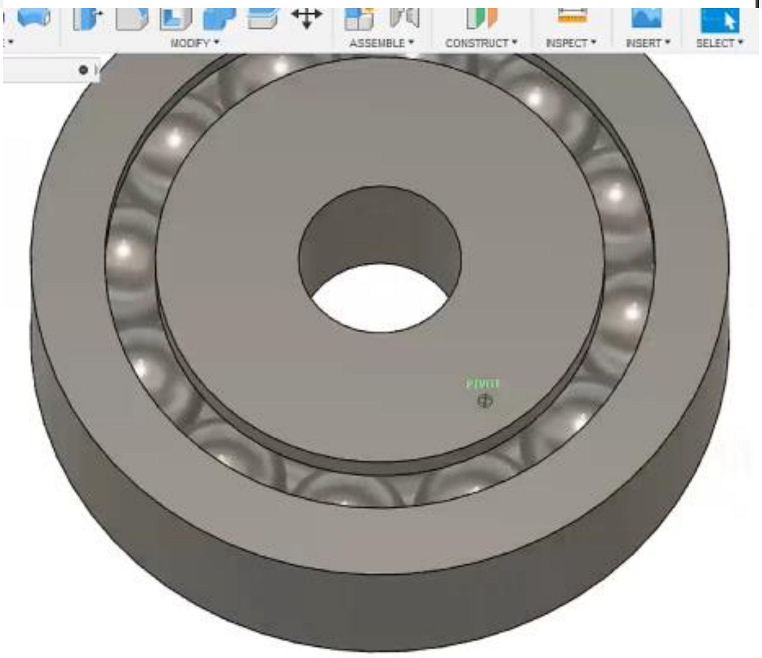
Optional – check by changing the ball diameter or number of balls.



42. Now we need to make the rest of the balls in the track. Select Create > Circular Pattern and then select the first ball, the origin green axis and then enter NumberOfBalls

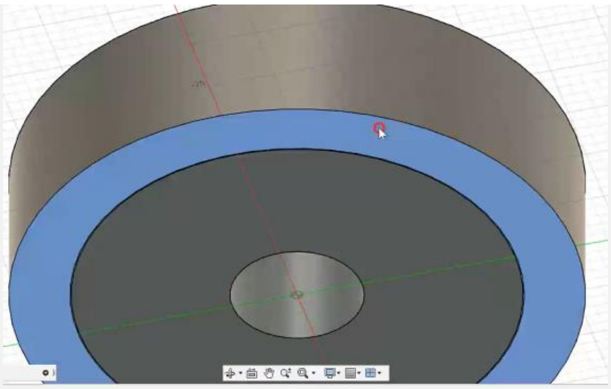


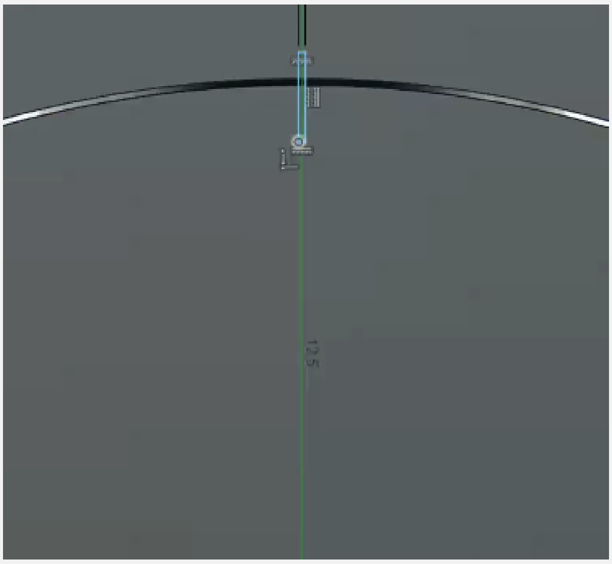
43. This is the full ball bearing.



44. The only thing left to do is get it ready for the 3D printer. The printer won't be able to take this in its current form because there are separate bodies so what we'll do is add a tiny bridge between each item to allow us to combine everything together.

    We're going to make a tiny bridge to connect the pieces up. This will be such a thin bridge that the pieces will snap apart once we start moving them after it has printed. Make a new sketch on the bottom side of the ball bearing. Draw a tiny rectangle that goes from one casing to the other through one of the spheres.

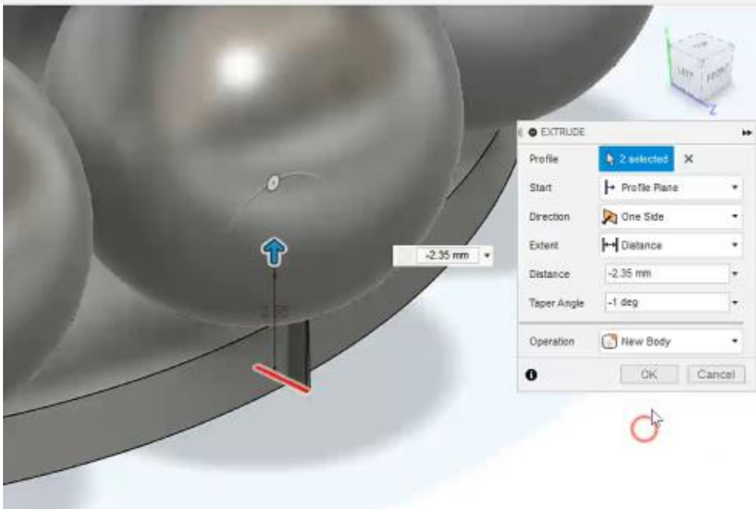




45. We need to extrude this bridge so that it touches all the parts of your ball bearing – the inner case, the outer case, and one of the balls at the same time.

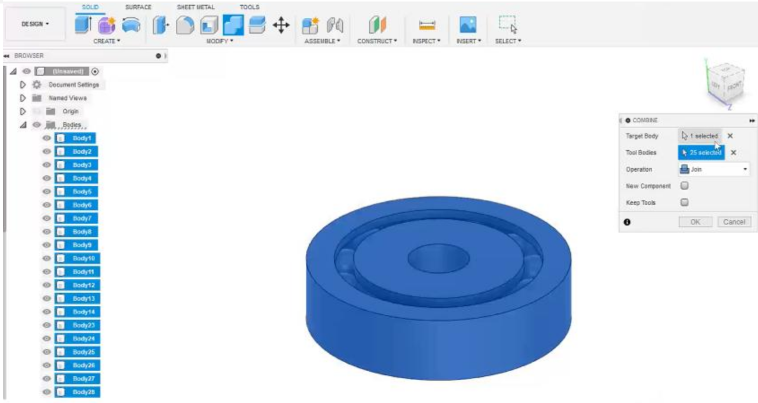
    I've hidden Body 2 (the outer case) here so you can see where the shape will be.

    Make sure this is a new body.



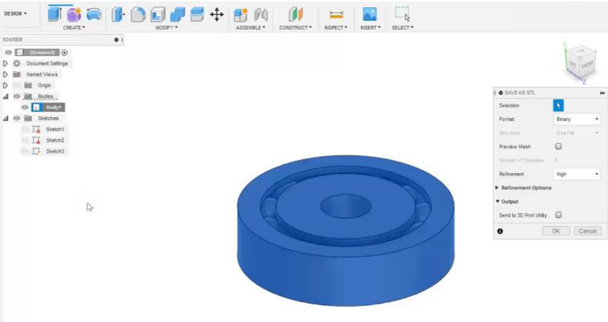
46. Create a circular pattern from that new body with the central vertical axis and the number of balls.

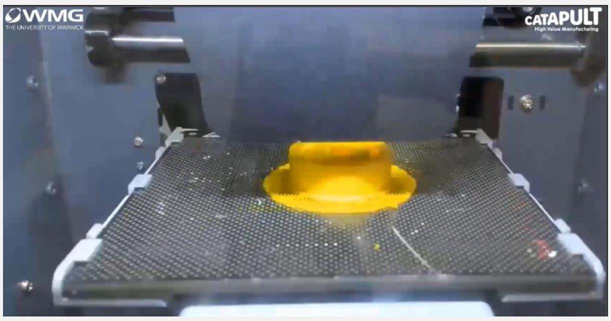
47. Combine everything!



48. Save your STL and head to your printer. Use tweezers to loosen the balls up so they can roll around freely.

Finally done!






M-PB-3