ME 371 Project 1

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Part and Report Overview

The part I have selected for this project is a metal teapot. I frequently use this teapot to brew tea each morning, and since it has an interesting shape and satisfied the design requirements for the project, I decided to reverse engineer this object. Images of the teapot from various views can be seen of the teapot with and without its lid (See Figures 1-8).

Figure 1. Front view of teapot with lid.

Figure 2. Side view of teapot with lid.

Figure 3. Top view of teapot with lid.

Figure 4. Bottom view of teapot.

Figure 5. Front view of teapot lid.

Figure 6. Top view of teapot lid.

Figure 7. Isometric view of teapot without a lid.

Figure 8. Top view of teapot without a lid.

Prior to modelling the object in SolidWorks, I made rough sketches of the teapot body and the teapot lid with measurements (See Figure 9 and 10). This report aims to give a comprehensive overview of the procedure taken to reverse engineer a teapot in SolidWorks. Measurement information, major milestones, and challenges faced during the modelling process will be described in detail in this report. The final product of this project will be an assembly of a teapot body and teapot lid that is an accurate representation of the real teapot that was modelled. Additionally, an engineering drawing will be made for both the teapot body and teapot lid. Upon completion of this project, I hope to gain more confidence using loft and sweep features within SolidWorks and learn valuable modelling techniques that will aid me in my future engineering career.

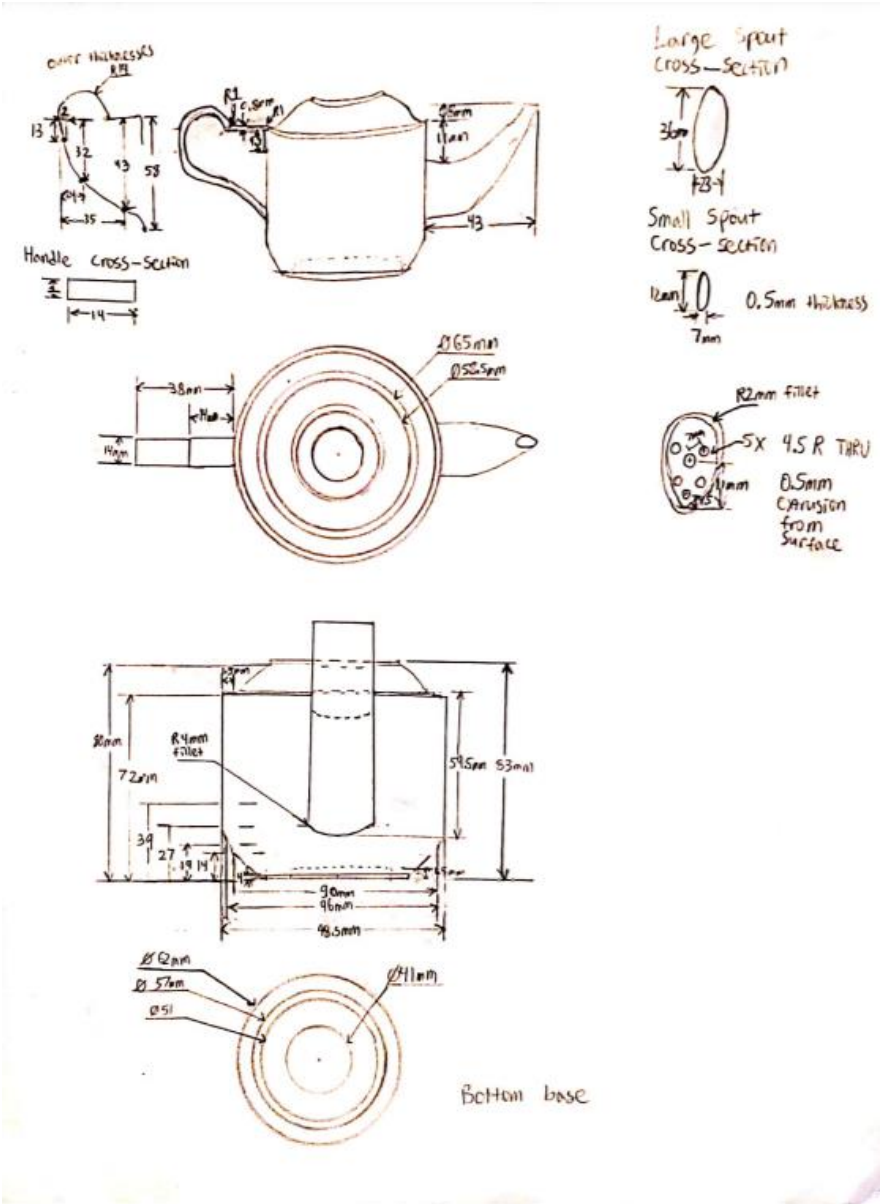

Figure 9. Overall rough sketch of all dimensions measured and used for the modelling of the teapot body.

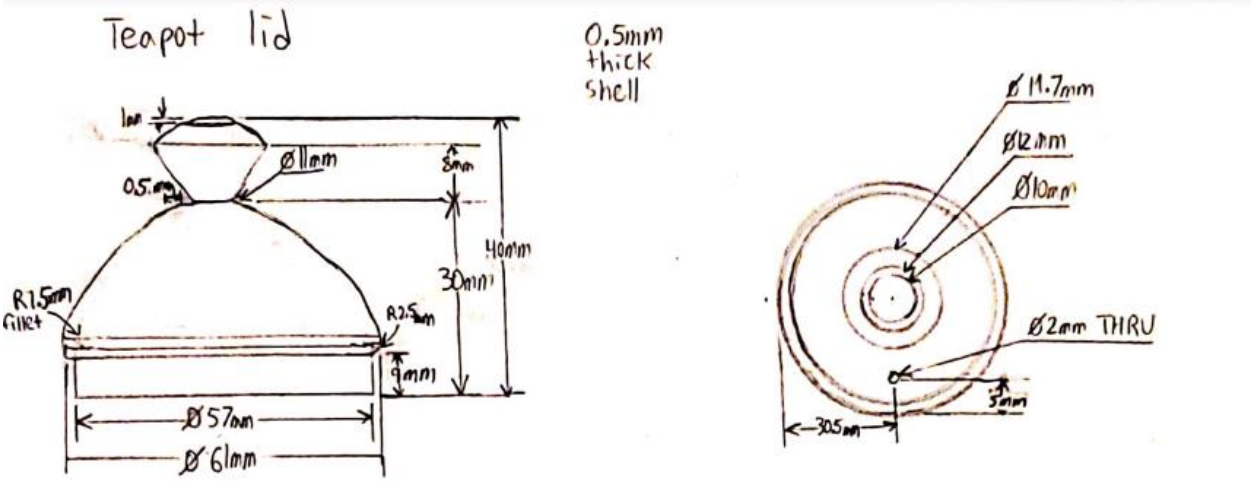

Figure 10. Overall rough sketch of all dimensions measured and used for the modelling of the teapot lid.

Component 1: Teapot Body

The first part of the teapot that was modelled was the base. A freehand sketch of the base that was used to model this section is shown below (See Figure 11). The base consists of one loft and a loft cut.

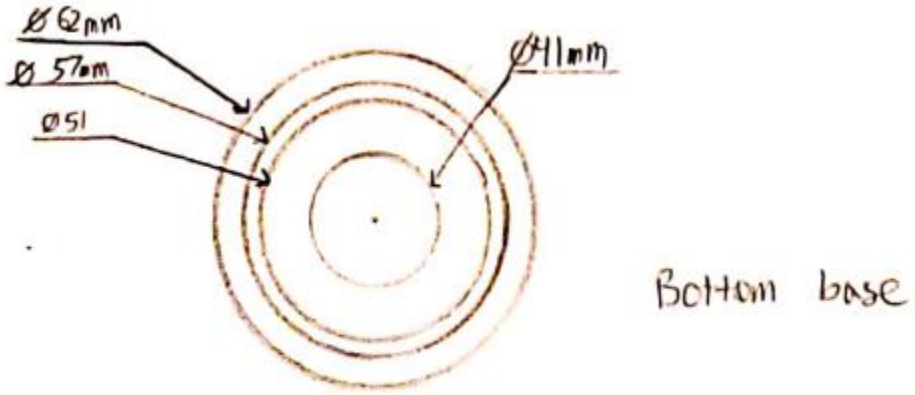

Figure 11. Rough sketch of teapot body base.

A visual glitch was observed when making the bottom base of the teapot (See Figure 12 below). The loft would cave inwards in between the section. There were no guide curves used for this loft. However, when the loft was deleted and made again between these two curved sections,

the curvature was not concave and displayed the desired curvature (See Figure 13). Both lofts had the same parameters, so it is unclear what was the root of this issue.

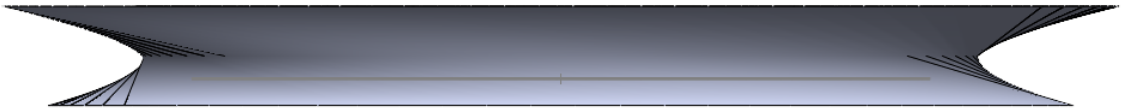

Figure 12. Visual glitch observed when making teapot base.

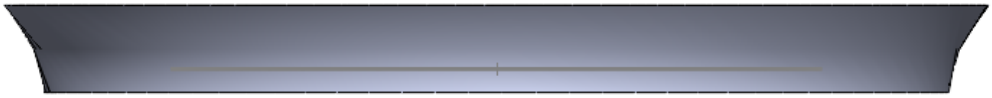

Figure 13. Corrected teapot base with same parameters as the loft in Figure 12.

The base also consists of a loft cut pictured in Figure 14 below. This loft is made of two sketches, with the innermost circle (with a diameter of 41 mm) being offset by 1.5mm in the y direction from the top plane. Initially, I thought that it would be possible for this feature to be made using two lofts. I made the concave portion using a loft first, and then another loft for the rest of the base. However, this did not produce the desired result since the loft for the concave section was convex and it was covered by the second loft. After doing further research online, I

discovered the loft cut feature, which produced the desired geometry. The final base can be seen below.

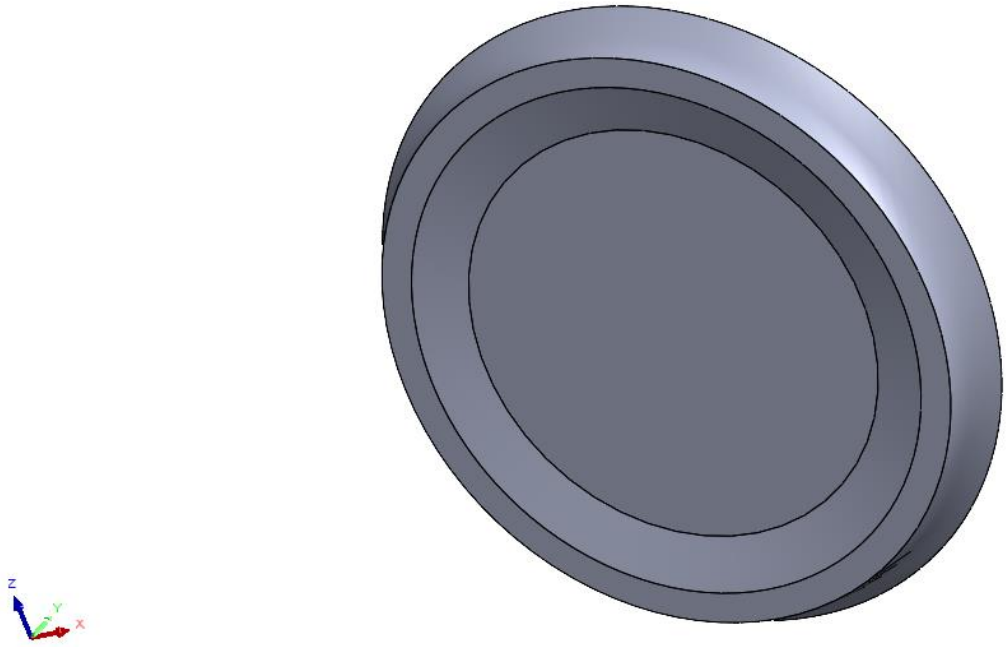

Figure 14. Completed teapot base which was made using a loft cut.

The body of the teapot was made using a single loft feature. The freehand sketch below shows the dimensions initially used for the body of the teapot (all dimensions without units specified are in millimeters) (See Figure 15). The horizontal markings on the body of the sketch were made using a dry erase marker on the teapot being modelled (See Figure 16). The vertical

distance between markings was measured using a ruler, and the diameter of the body at each horizontal marking was measured using a caliper.

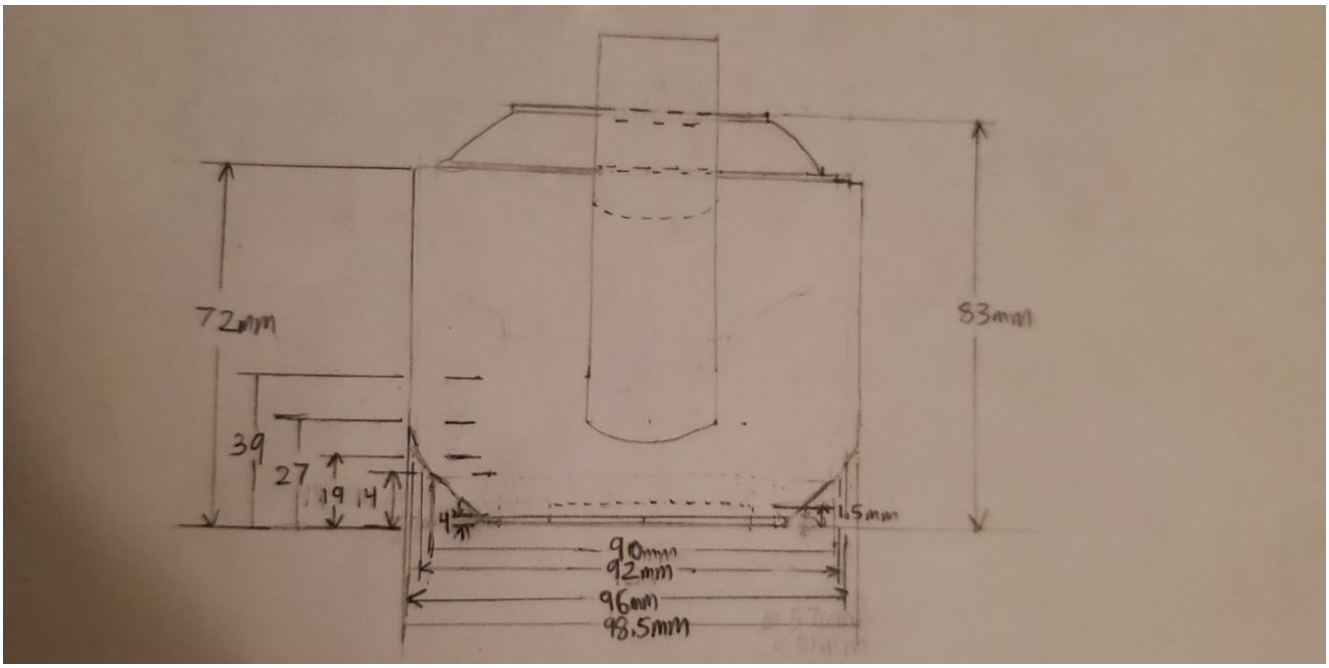

Figure 15. Initial measurements made for the teapot body. Horizontal markings represent where markings were made with a dry erase marker.

Figure 16. Close up view of markings made on the teapot body with a dry erase marker.

Initially, the loft was made using diameter readings at six vertical markings. When the loft was made in SolidWorks, the surface had a warped appearance (See Figure 17). I added more measurements in between the planes where the surface appeared to be warped, but the resulting surface was still visibly warped.

Figure 17. Warped teapot body produced from initial loft attempt.

I overcame this issue by removing the sketches that caused the warpage and measured the diameters at more easily measurable markings. This approach avoided intermediate points at curvatures that were difficult to measure. The resulting loft consisted of four sketches instead of six, had a smooth surface and was accurate to the object being modelled (See Figure 18-21).

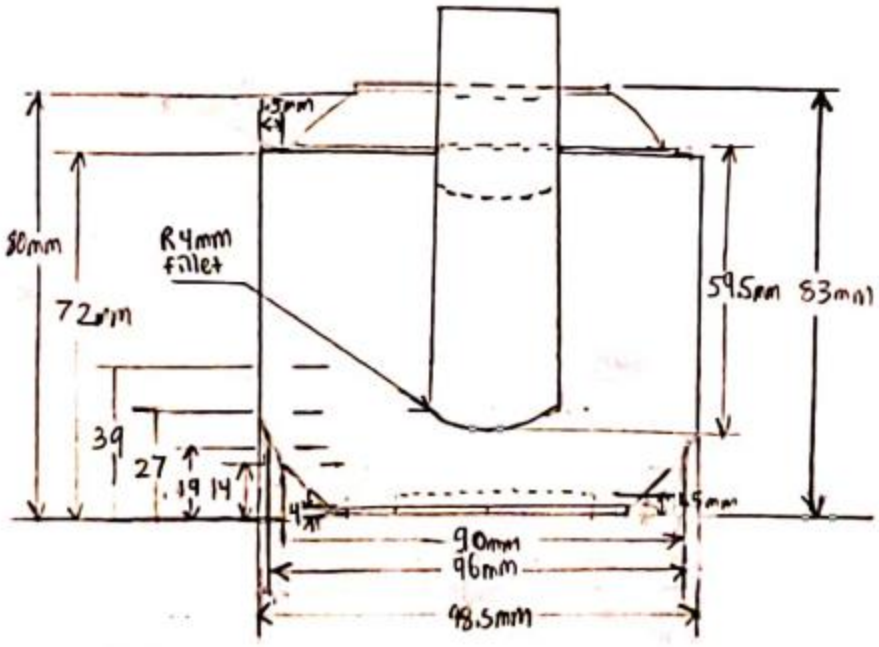

Figure 18. Revised measurements made for the teapot body. Horizontal markings represent where markings were made with a dry erase marker.

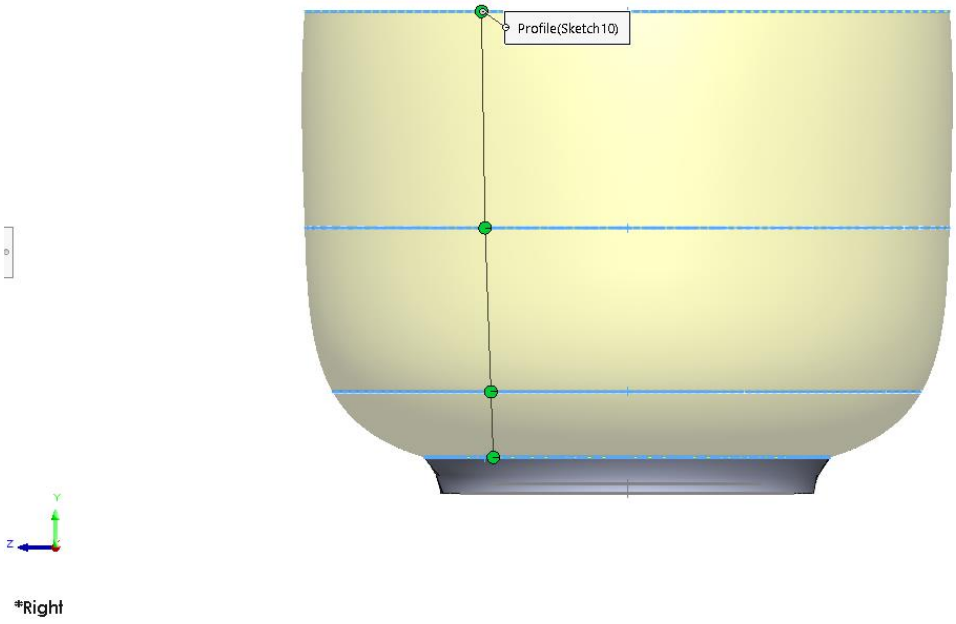

Figure 19. Revised loft for the teapot body within SolidWorks.

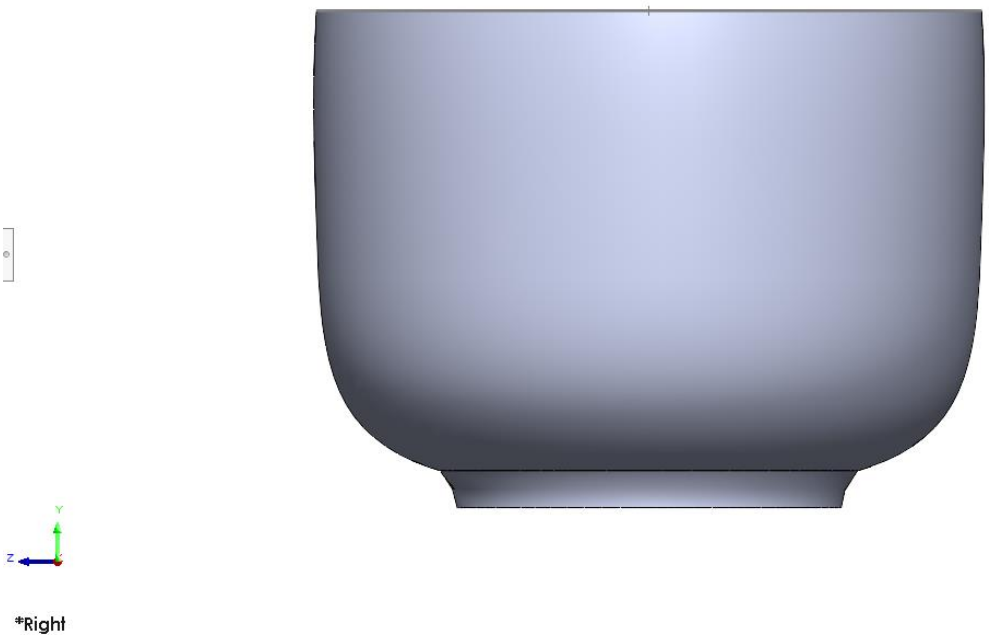

Figure 20. Right view of revised loft.

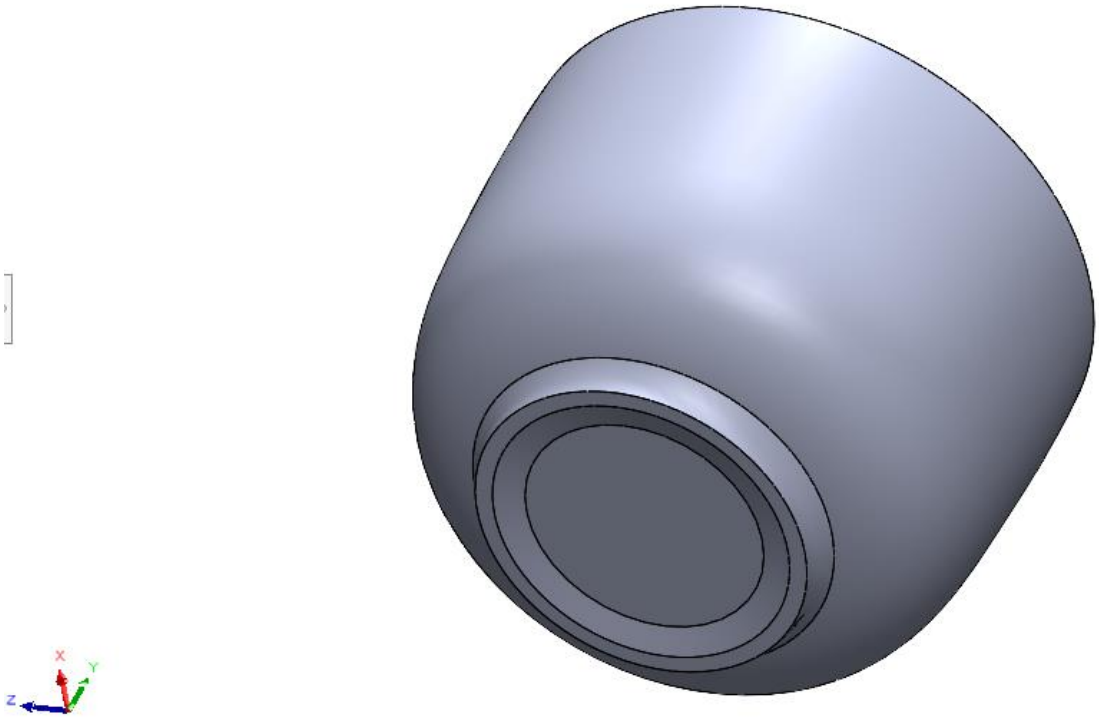

Figure 21. View showing both the completed bottom base and main body of the teapot.

Once the main body of the teapot was complete, two more lofts were made on top of the circular edge of the body of the teapot. Measurements for these lofts were made using a ruler to measure vertical distances and a caliper to measure diameters. These measurements can be seen in the rough sketch made for this portion of the teapot in Figure 22. These lofts did not have any guide curves because they assumed a desired curvature when initially made in SolidWorks. Once the lofts were complete, a 3mm shell was made from the top face of the teapot body. A cut extrude was then made to remove excess material from the lip of the teapot to satisfy the 58.5mm diameter hole made to fit the teapot lid (see Figure 22). An isometric and side view of the completed teapot body with the upper portion complete can be seen in Figures 23 and 24 respectively.

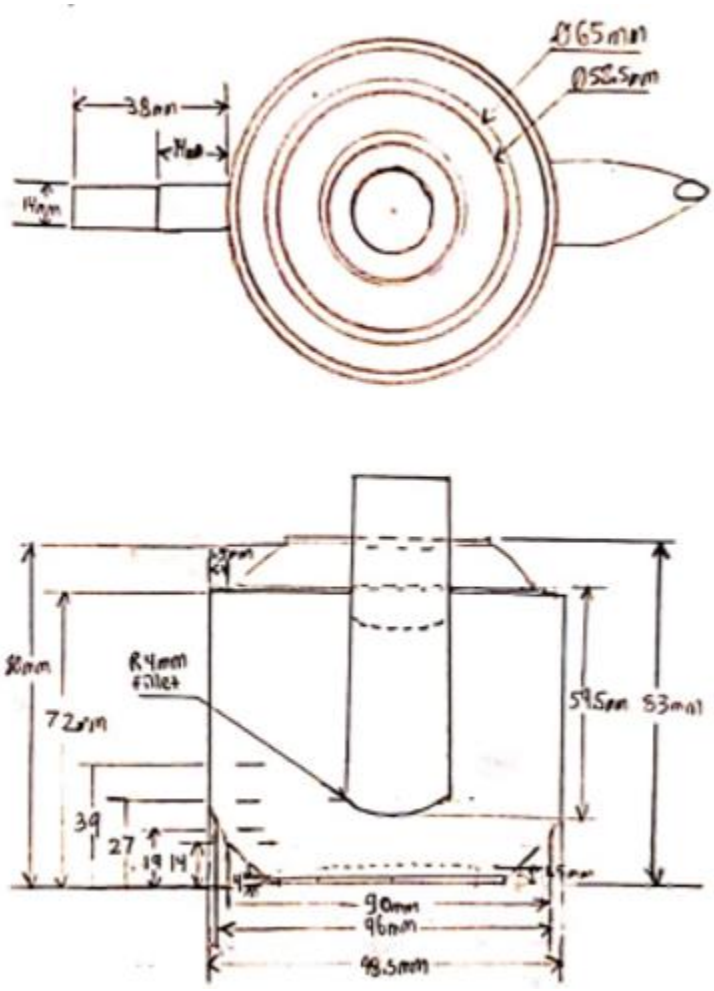

Figure 22. Rough Sketch used to make the teapot body.

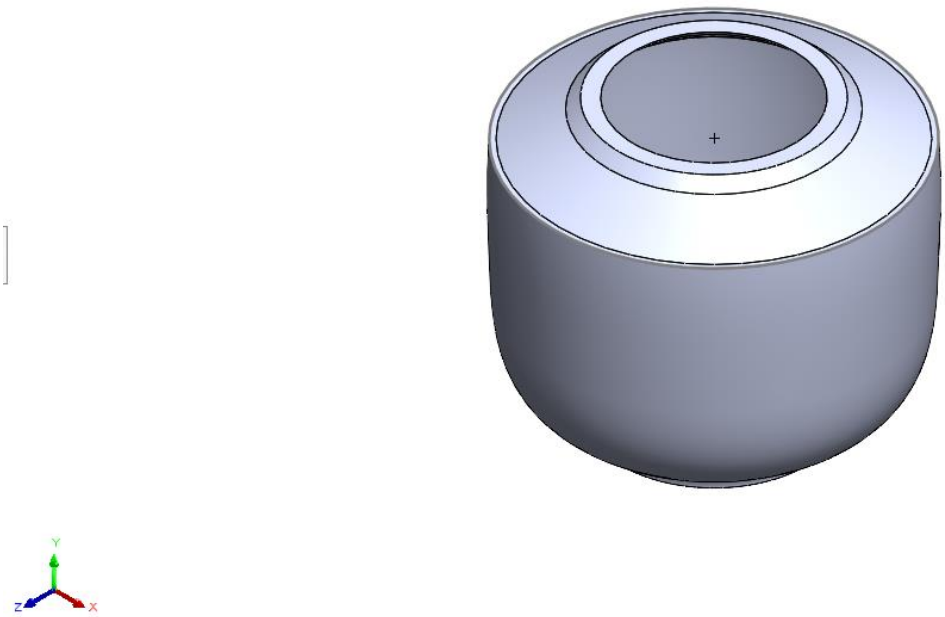

Figure 23. Isometric view of the completed body of teapot with upper portion of the body.

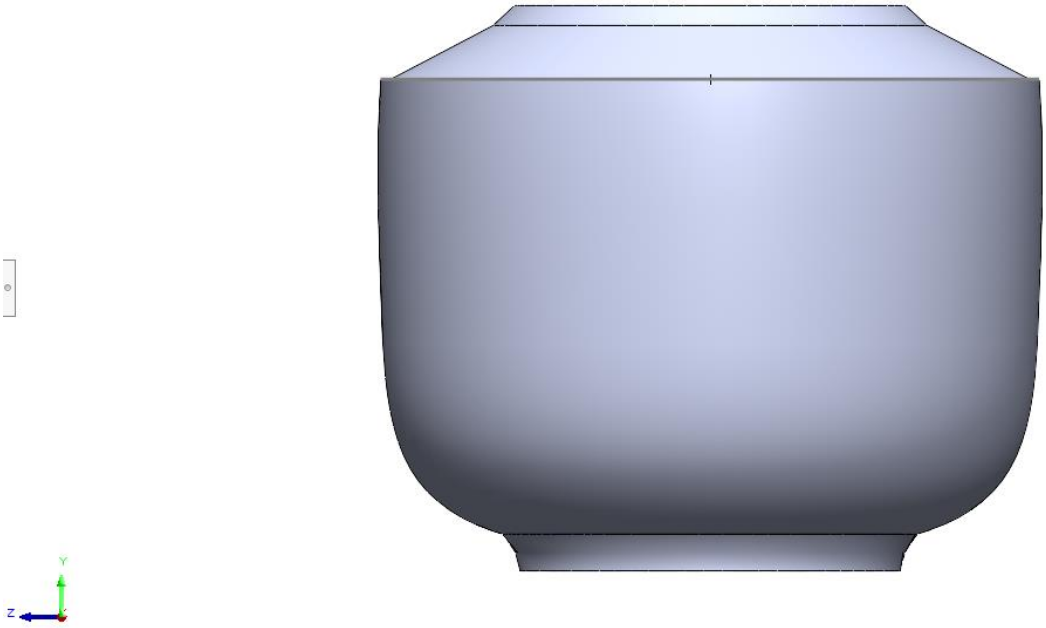

Figure 24. Side view of the completed body of teapot with upper portion of the body.

The overall spout dimensions were made using a ruler and a caliper. A rough sketch showing the spout dimensions and large and small elliptical cross-sections of the spout are shown in Figures 25 and 26 respectively.

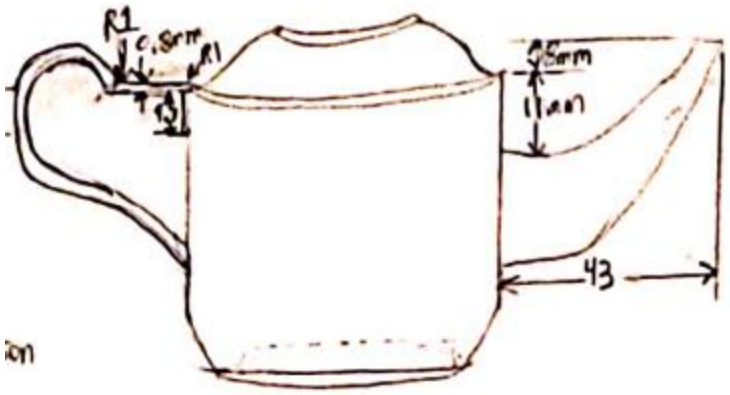

Figure 25. Rough sketch of measurements used to model the teapot spout.

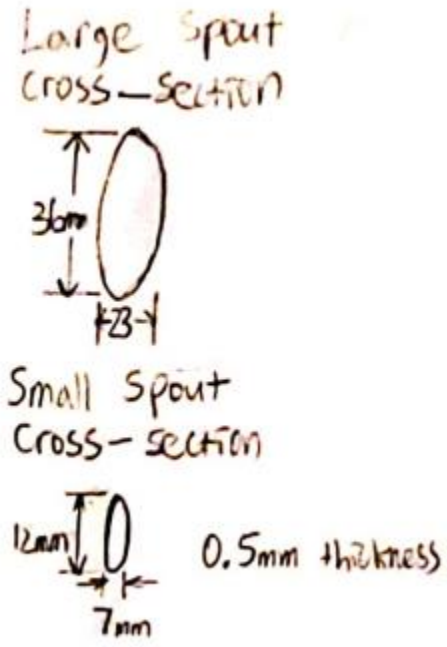

Figure 26. Rough sketch of surface areas used to make loft for teapot spout.

To replicate the curvature of the teapot spout in SolidWorks, I utilized the Sketch Picture feature in sketch tools. Figure 27 is the image I used to create the guide curves for the loft I used to make the spout. I created a line on the Sketch picture that had the same measurement as the height of the teapot body. I then rescaled this image so that the height of the teapot body in the image matched the actual height of the teapot. I then overlayed the body of the teapot on top of the model of the teapot that was modelled to isolate the spout in the image. An overlay of these parts can be seen in Figure 28.

*Front

Figure 27. Image used as a reference image for the modelling of the teapot spout.

*Front

Figure 28. Scaled image with SolidWorks model overlayed.

From here, I used two 3D splines and the curvature in the picture to connect the two ellipses to each other. I then used the loft feature to create the spout. The result with the image in the background can be seen in the figure below.

Figure 29. Teaapot with spout overlayed on the reference image.

When I hid the reference picture I used to create the loft for the spout, I observed a gap between the body of the teapot and the teapot spout (See Figure 30).

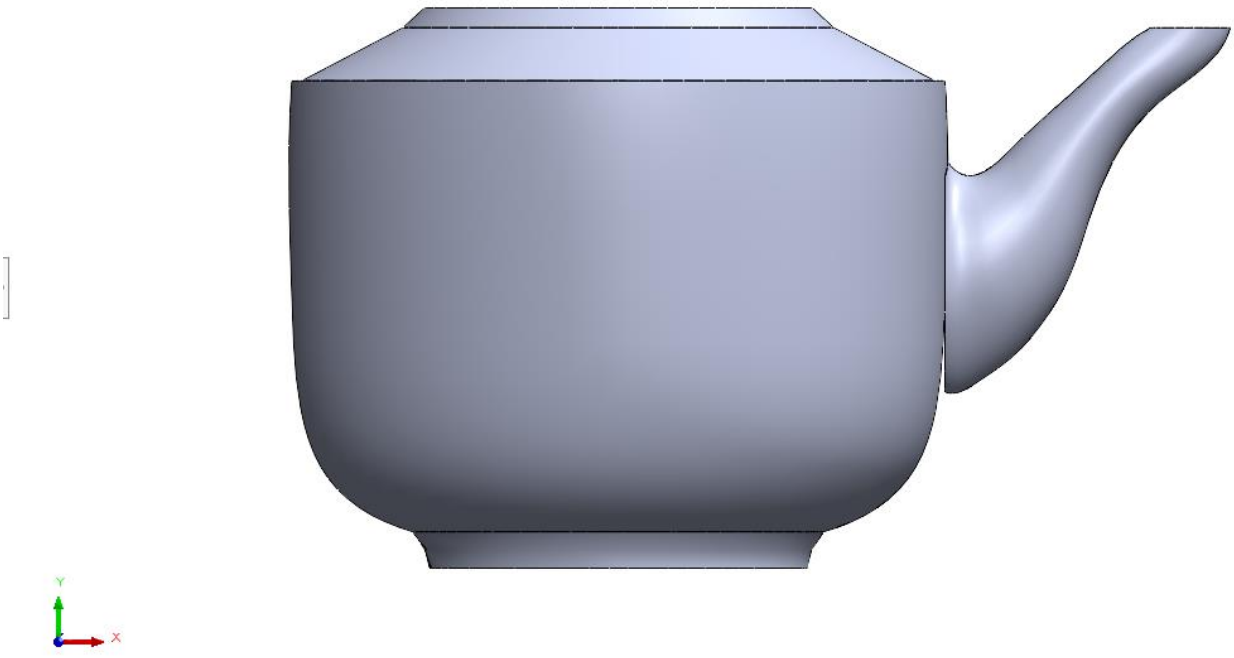

Figure 30. A visible gap can be observed between the surface of the teapot body and the bottom of the teapot spout.

This issue occurred because the plane that I used to sketch the large cross-sectional area of the spout was on a plane that was 49.25mm (the radius of the upper portion of the teapot body) away from the center of the teapot. This plane was tangent to the curvature of the teapot, and it did not follow the curvature of the teapot surface.

Initially, I tried to remedy this issue by moving the reference plane to be inside the teapot body surface. After further evaluation of this approach, this would mean I would need to adjust all my spout measurements to account for this change. This plane approach also caused the top of the larger ellipse to be pushed inwards into the surface of the teapot body which resulted in warpage (See Figures 31-33).

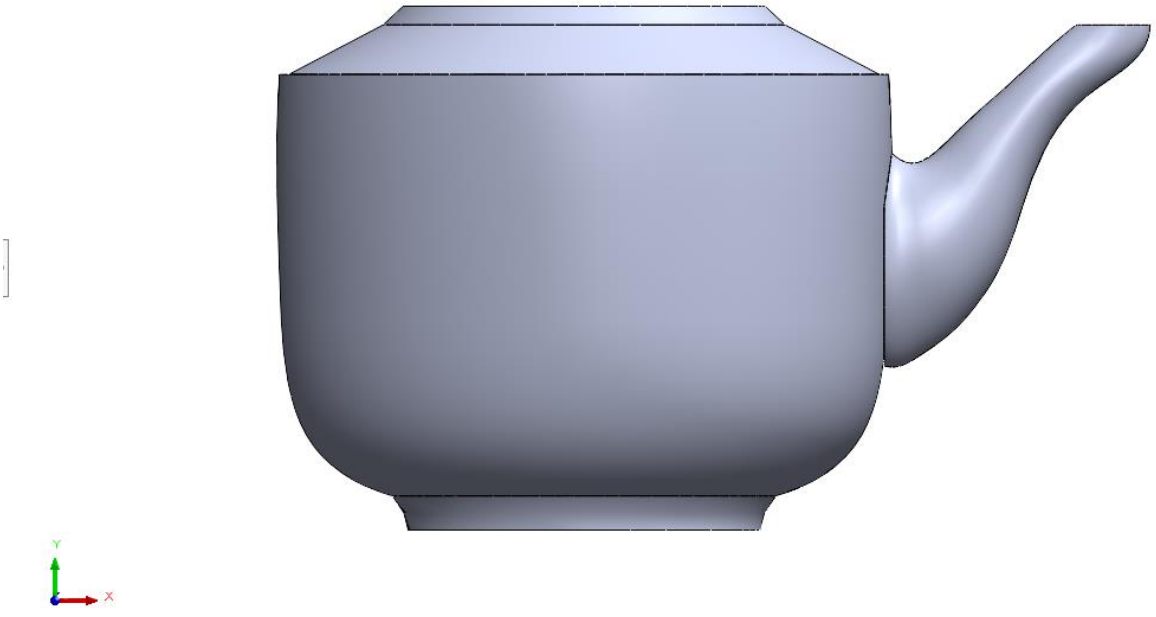

Figure 31. Front view of attempted solution to fix gap.

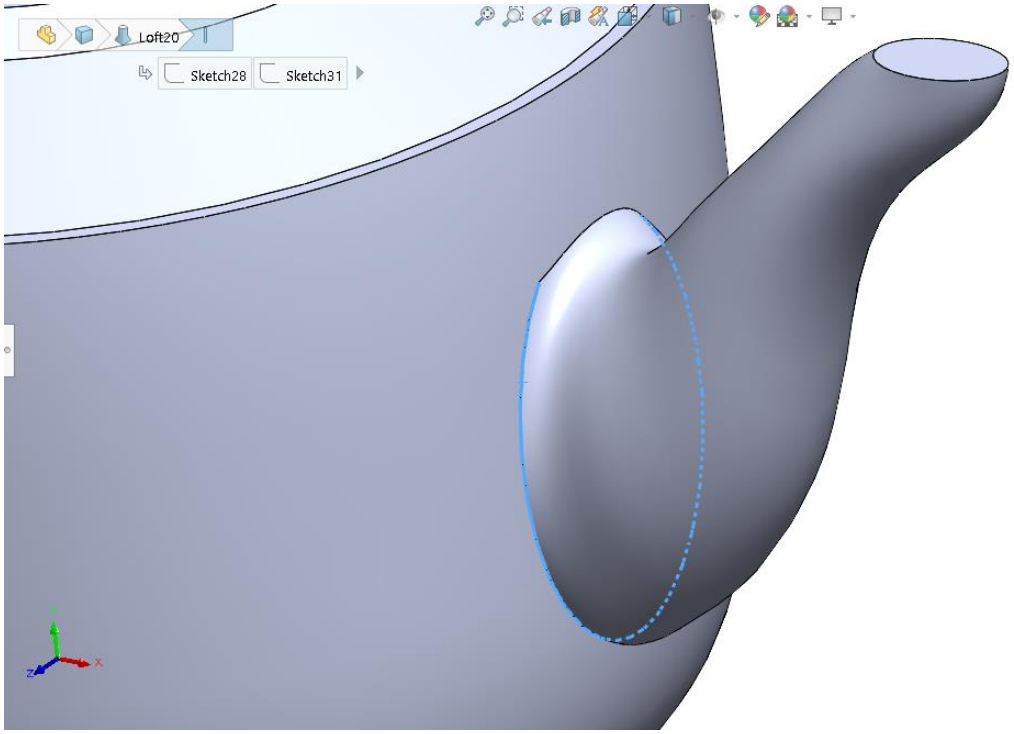

Figure 32. Close up view of attempted solution to fix gap.The large elliptical cross section is inside the surface of the teapot.

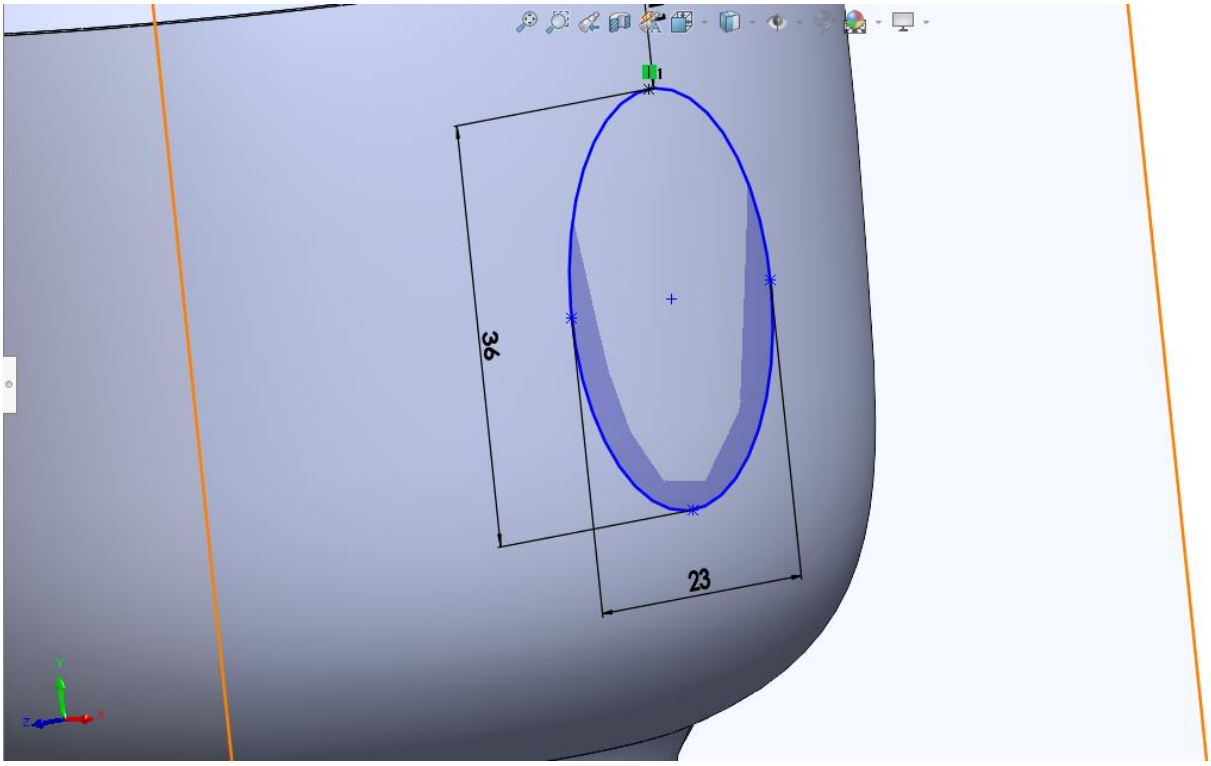

Figure 33. Sketch view of Figure 32 in SolidWorks.

Then, I used the project curve feature to project the larger ellipse on the curved surface of the teapot body. However, this did not produce a lofted surface since the projected curve was not truly on the curved surface. I after doing more research, I came across a feature called split line, which projected a fully defined sketch of the ellipse on the curved surface of the teapot (See Figure 34). Using this newly made sketch as a reference, and the 3d spline guide curves previously made, the loft was successfully made (See Figure 35).

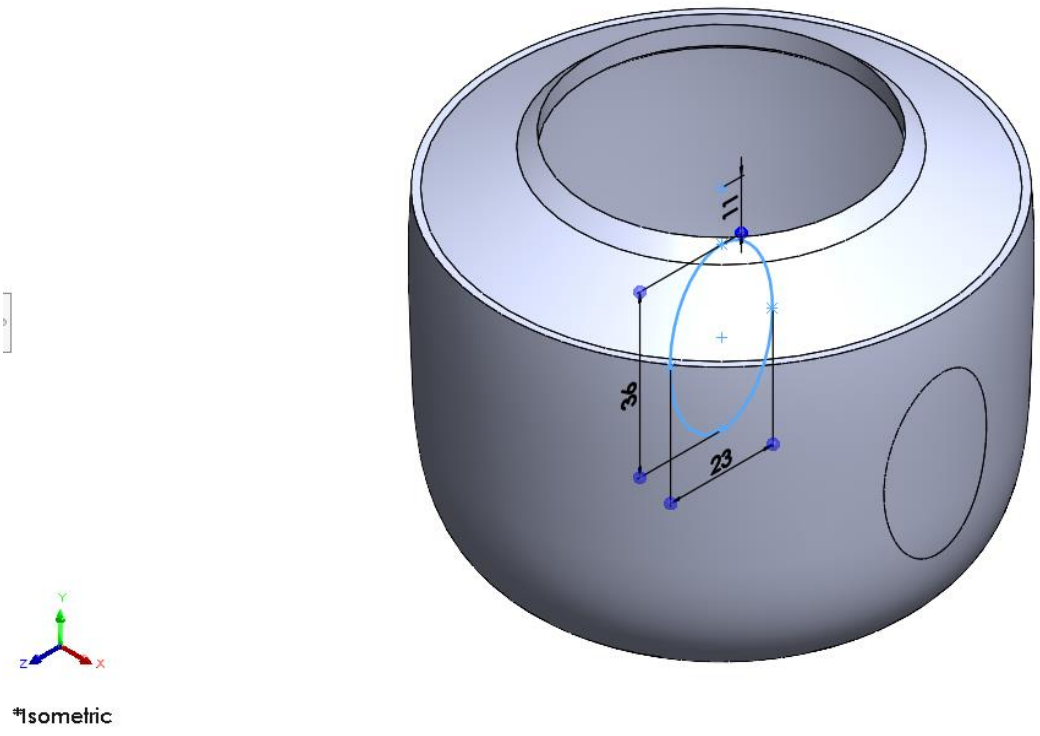

Figure 34. Elliptical face projected on surface of the body using the split line function.

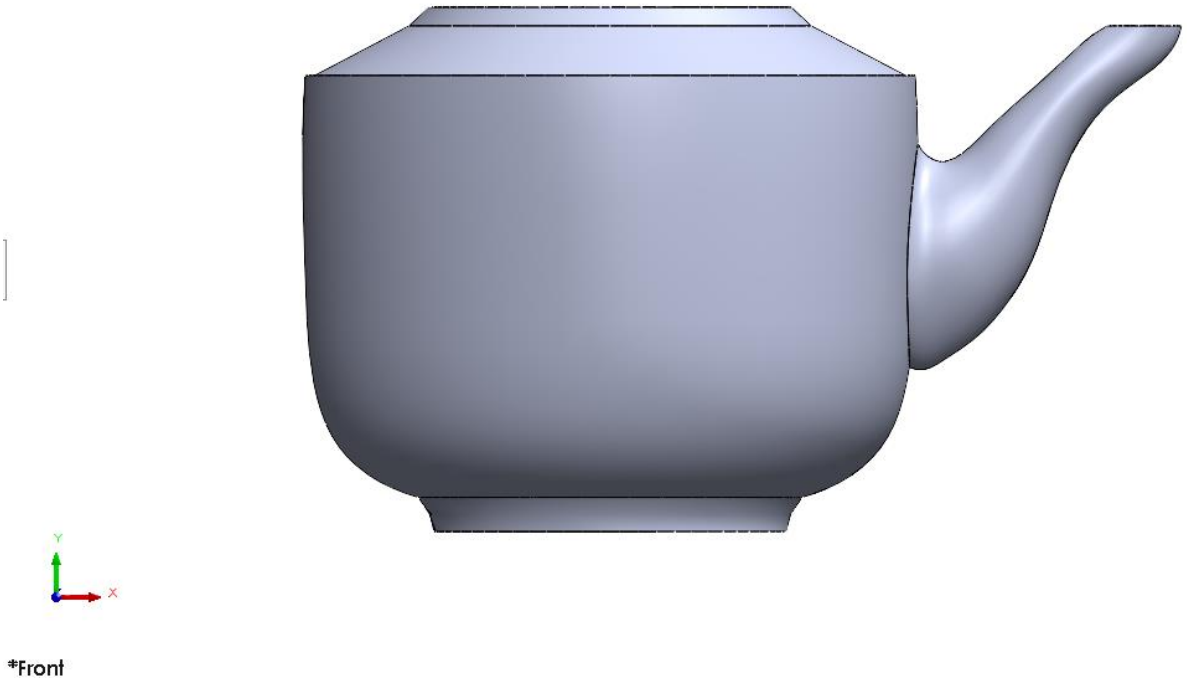

Figure 35. Spout created from elliptical face projected on surface of the body using the split line function.

The teapot had an angled cut on the spout (See Figure 36), so I used the reference image to make a cut to remove excess material from the spout (See Figure 37). After the extruded cut was made, I used the shell feature to give the spout a thickness of 0.5mm. A front and isometric view of the teapot can be seen in Figures 38 and 39 respectively.

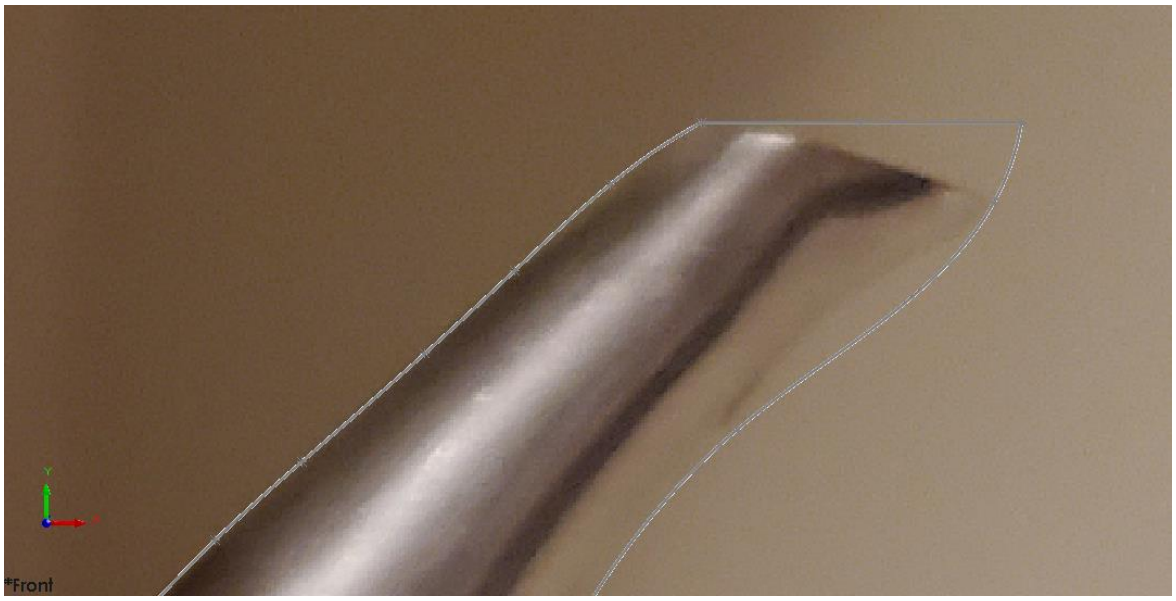

Figure 36. Close up of angled cut from reference image of teapot.

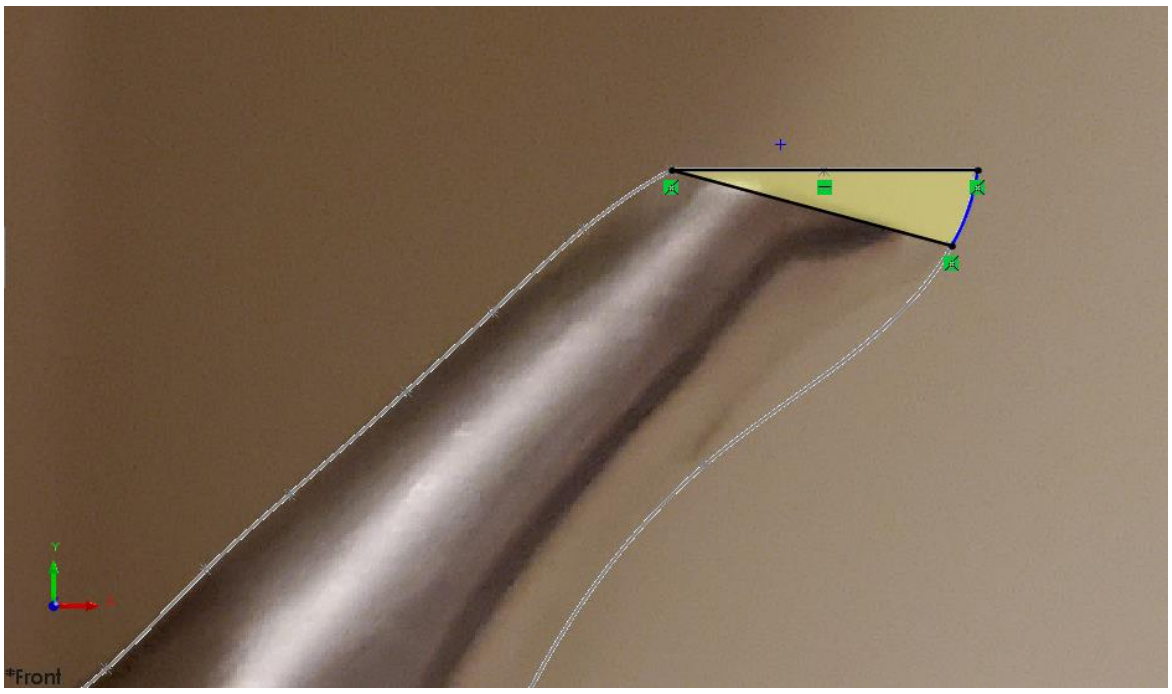

Figure 37. Sketch view of the cut made using the reference image to measure the angled cut.

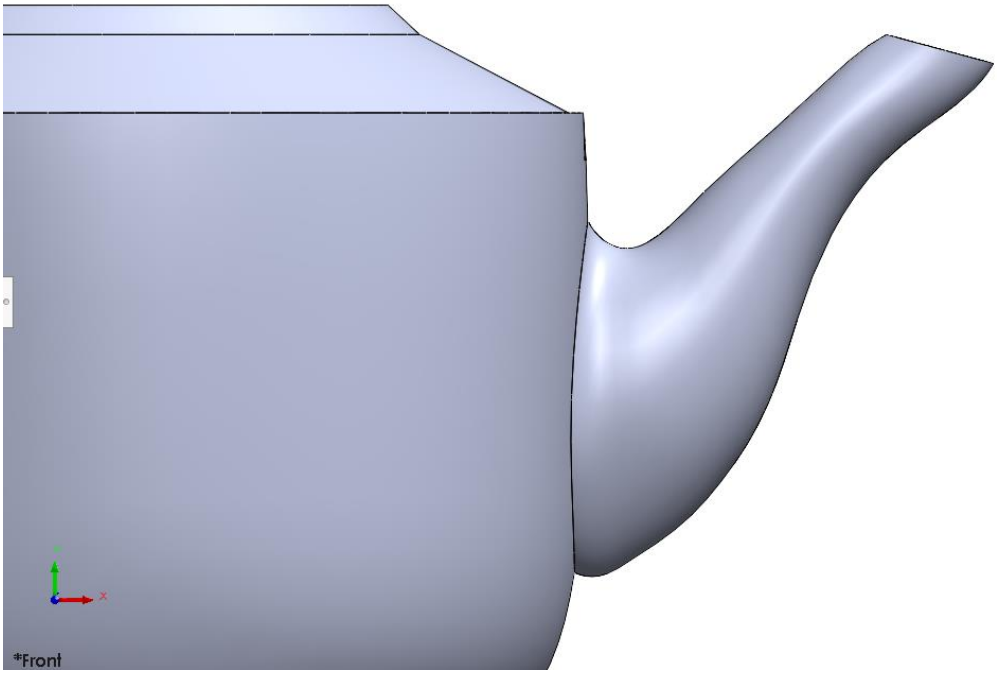

Figure 38. Front view of completed spout with angled cut.

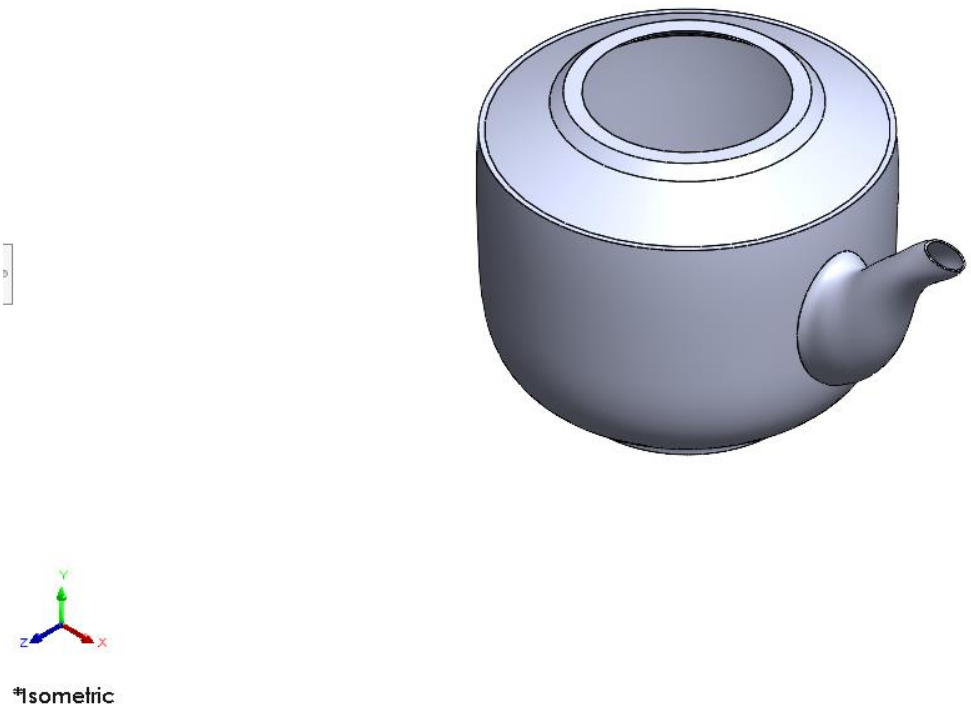

Figure 39. Isometric view of completed spout with angled cut.

At this point in the design, I realized that the image that I had been using as reference for my guide curves was not perfectly parallel with the object I was modelling. After taking extra steps to ensure that my image was parallel by enabling a setting on my smartphone camera, the image below (Figure 40) was used as reference for the spout guide curves. I also adjusted both the width and the height of the image when scaling the image to match both the width and height of the teapot to obtain a more accurate reference image. Previously, I had only used the height of the teapot to scale my reference image.

Figure 40. Revised reference image for teapot.

Following the previously described procedure for making the teapot spout from a reference image, the teapot spout was remade. A front view and isometric view of the teapot with the corrected spout is shown below (See Figures 41 and 42).

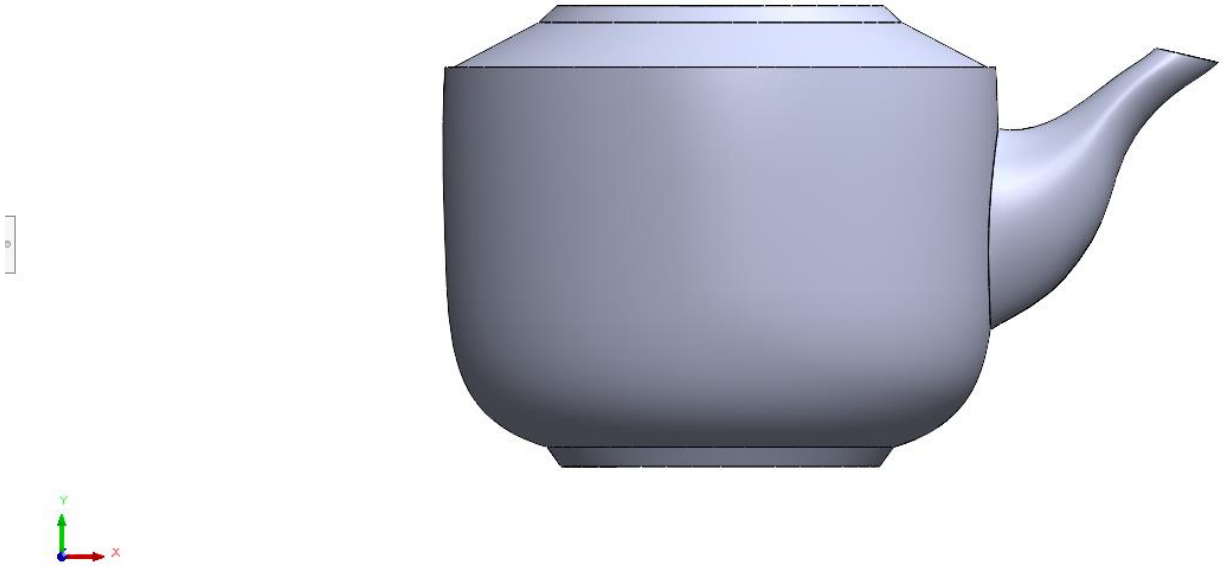

Figure 41. Front view of corrected spout with angled cut.

Figure 42. Isometric view of corrected spout with angled cut.

The teapot I modelled had holes at the base of the spout to allow tea to flow through them but prevent tea leaves from passing through the holes (See Figure 43). I used a caliper to make each of the measurements shown in the rough sketch (See Figure 44). Using a series of extruded bosses and cuts based on the measurements taken from the sketch, this portion of the spout is shown in Figure 45.

Figure 43. Holes made inside teapot to allow water to pass through but keep tea leaves from passing.

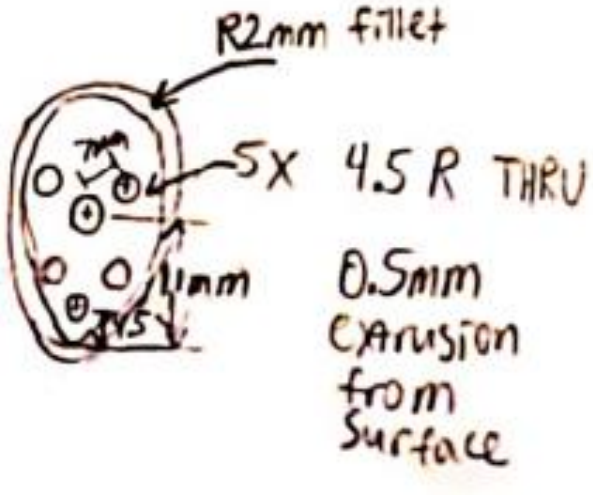

Figure 44. Rough sketch with measurements of holes made inside teapot to allow water to pass through but keep tea leaves from passing.

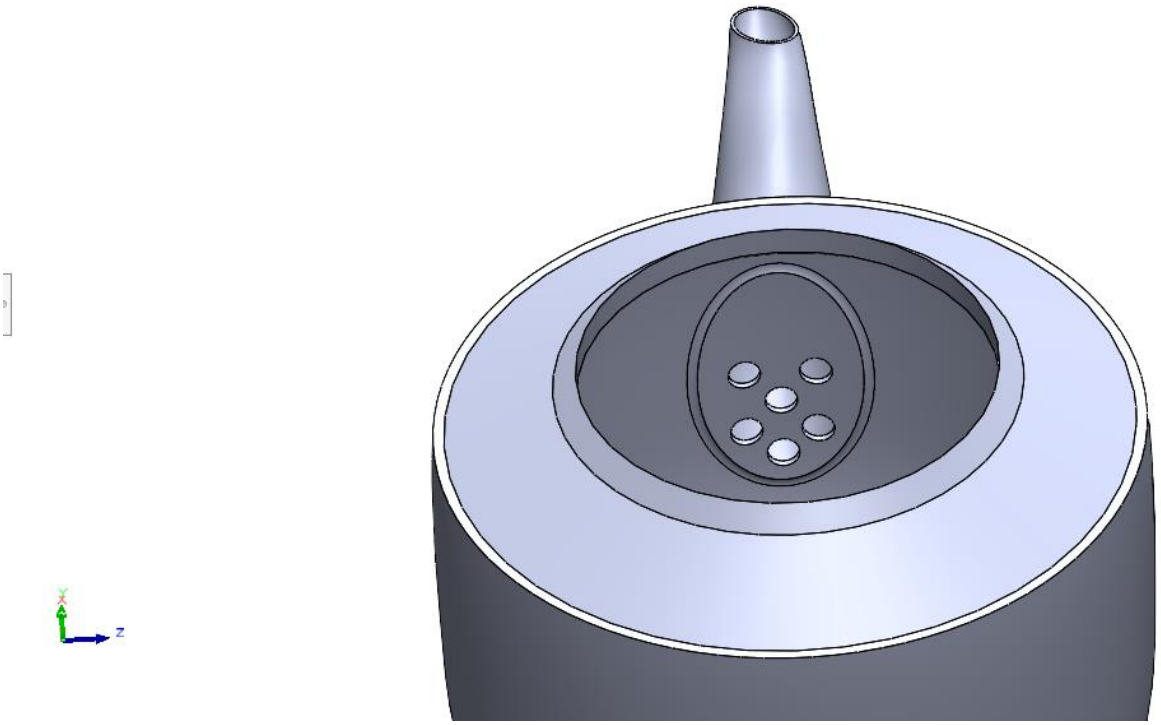

Figure 45. SolidWorks view of holes in teapot.

The final portion of the teapot body is the handle of the teapot. Initially, I tried using the reference image I used to make the teapot spout to trace the curvature of the handle. However, I quickly realized that since the handle followed the surface of the teapot body, the entire handle was not visible in the reference image to make an accurate sketch. Instead, I took a more conservative approach to measuring the handle by using a caliper, a ruler, and a dry erase

marker. The non-curved portions of the handle were made using a caliper and ruler. For the curved portion of the handle, I used a dry erase marker to mark a few points along the handle. Then using a ruler, I measured the vertical and horizontal distances of each of these points. The measurements defining the points I used for the handle are shown as dots on the freehand sketch of the handle (See Figure 46). Once the points were sketched in SolidWorks, I used a spline to connect the points to each other and added a tangent relation between the arc of the handle and the newly made spline. Then using the rectangular cross section shown in Figure 46, I used the sweep function to make the handle. Four four-millimeter fillets were then added to the handle as shown in Figure 47.

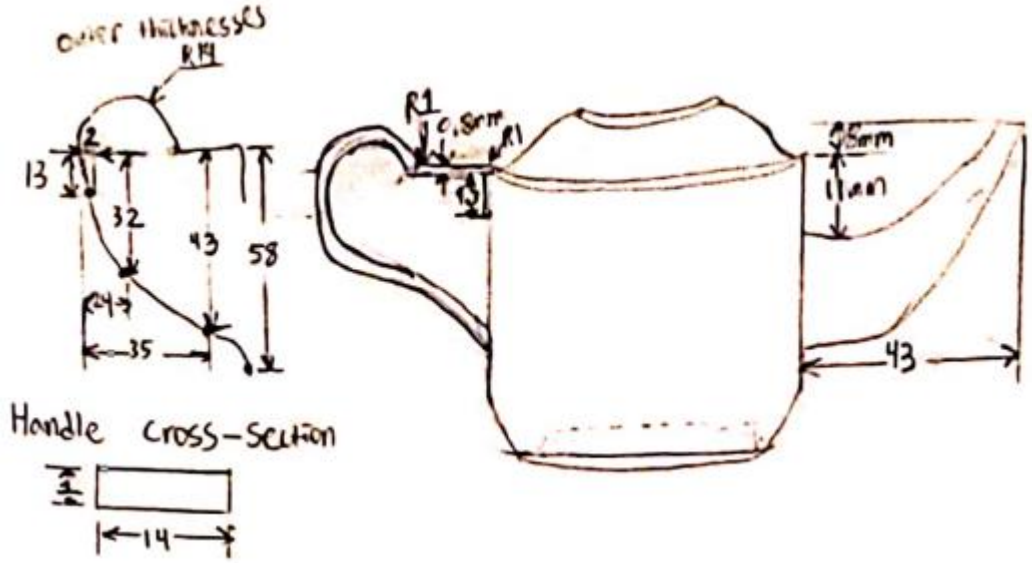

Figure 46. Rough sketch with measurements used to create the sweep for the teapot handle.

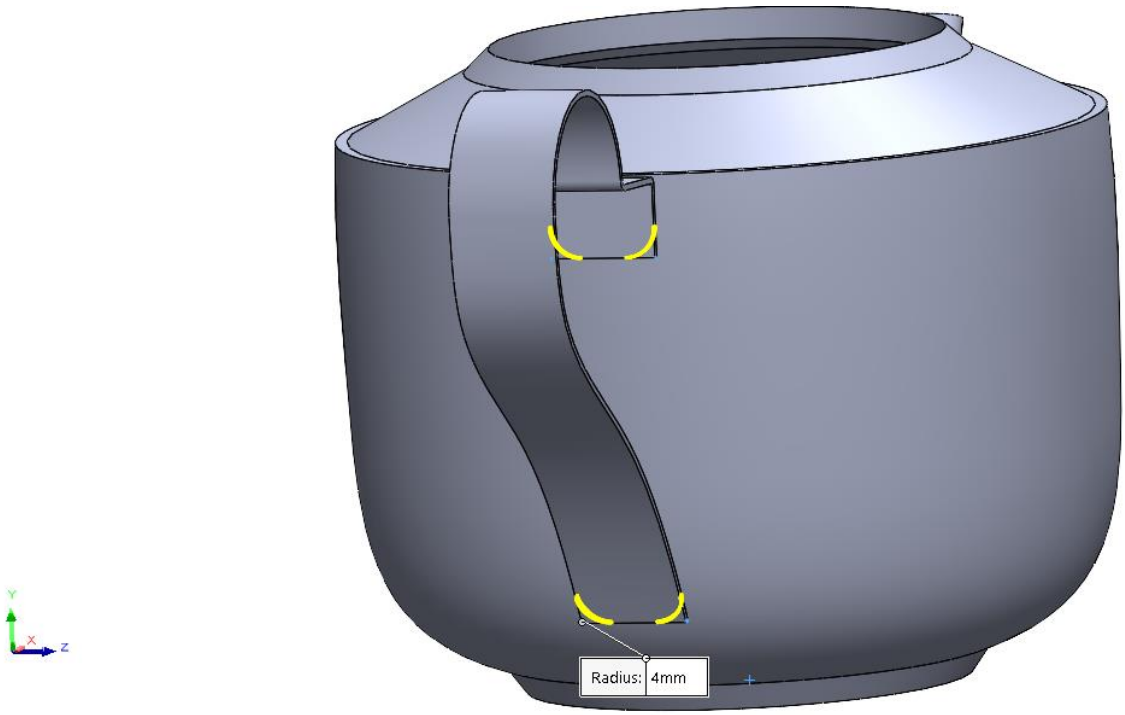

Figure 47. Location of the four 4 mm radius fillets on the teapot handle.

A view of the completed handle can be seen in Figure 48. A front, side, top and isometric view of the completed teapot body with a spout and handle is shown in Figures 48-51 respectively.

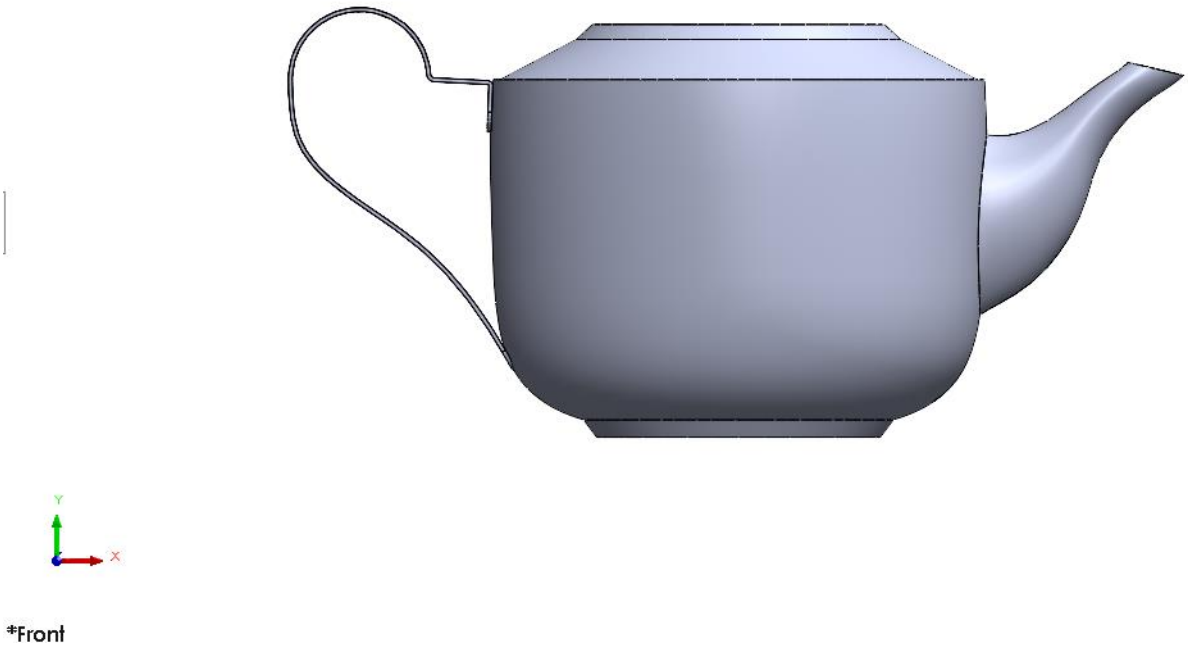

Figure 48. Front view of completed teapot body with handle and spout.

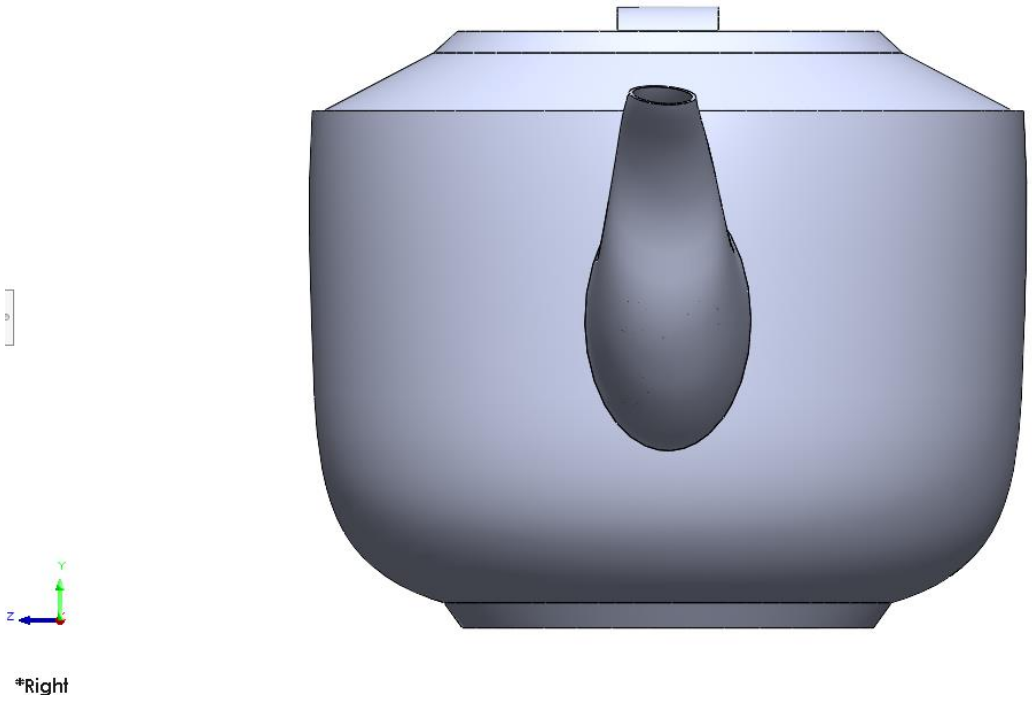

Figure 49. Right view of completed teapot body with handle and spout.

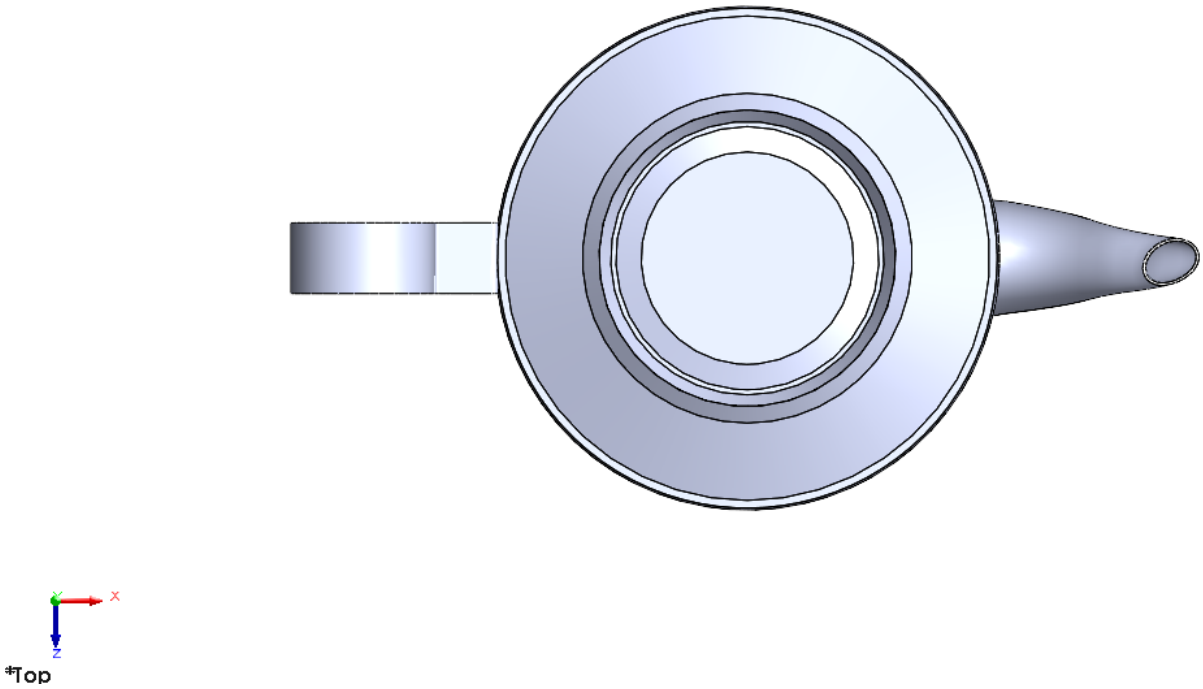

Figure 50. Top view of completed teapot body with handle and spout.

Figure 51. Isometric view of completed teapot body with handle and spout.

Component 2: Teapot Lid

The second component of the teapot that was modelled was the teapot lid. The rough sketch used to model this part can be seen in Figure 52. All dimensions are in millimeters and were made using a ruler to measure vertical and horizontal distances and a caliper to measure diameters.

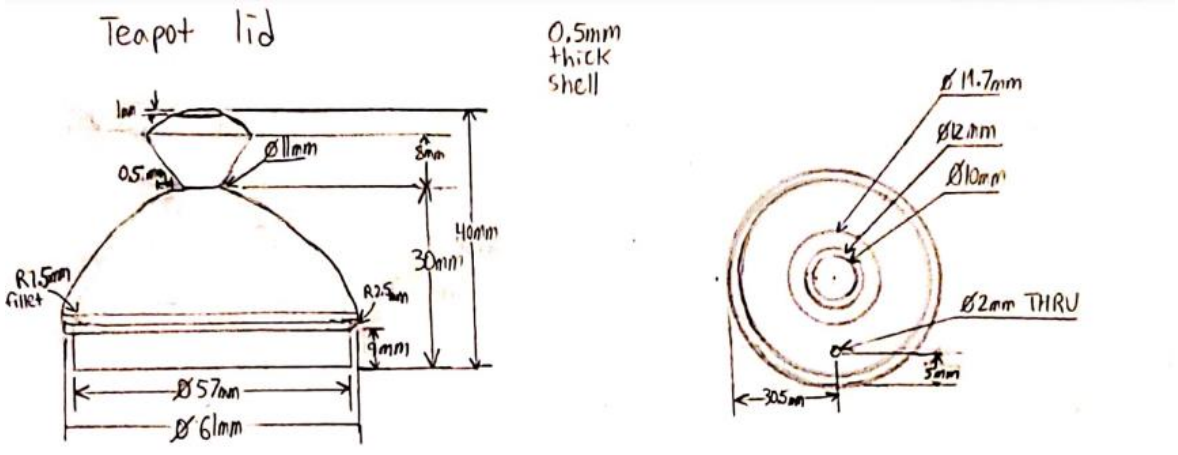

Figure 52. Rough sketch with measurements used to model the teapot lid.

Using the dimensions shown above, a boss extrude was made in SolidWorks (See Figure 53 below).

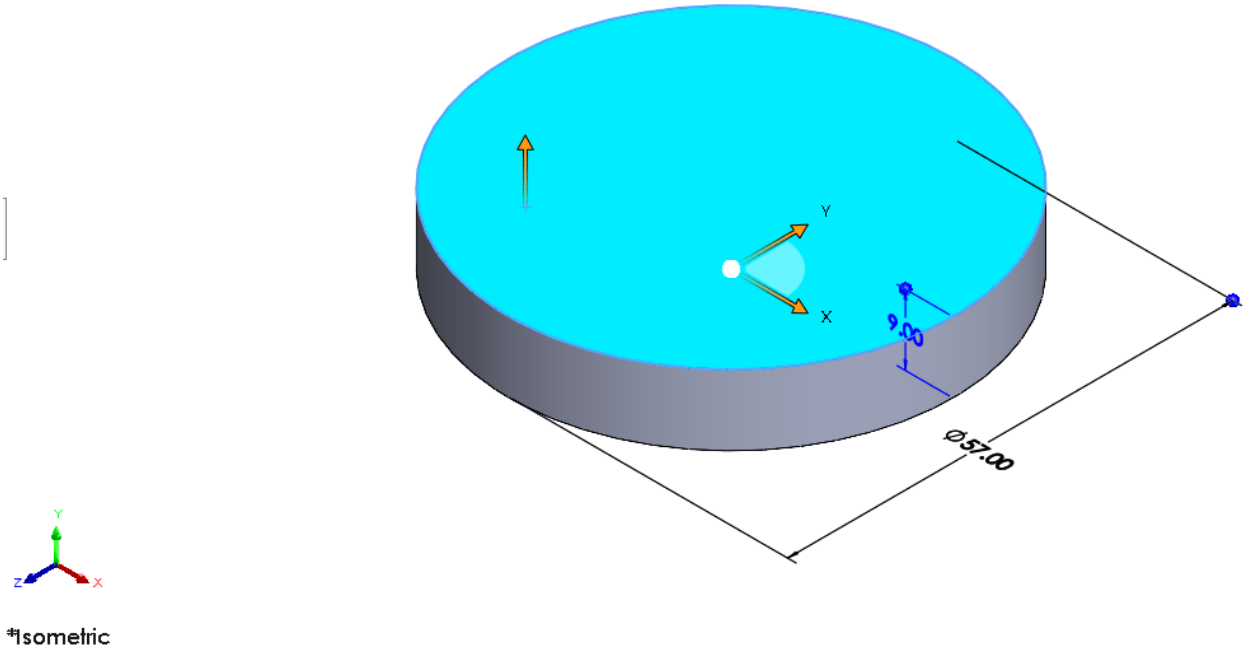

Figure 53. First boss exttude made in SolidWorks for teapot lid.

Then, two lofts were made according to the dimensions shown in the images (See Figure 52). The dimensions in the y direction are measured from the top plane (See Figure 54). The edge between two lofted sections was then filleted with a five-millimeter fillet (See Figure 55).

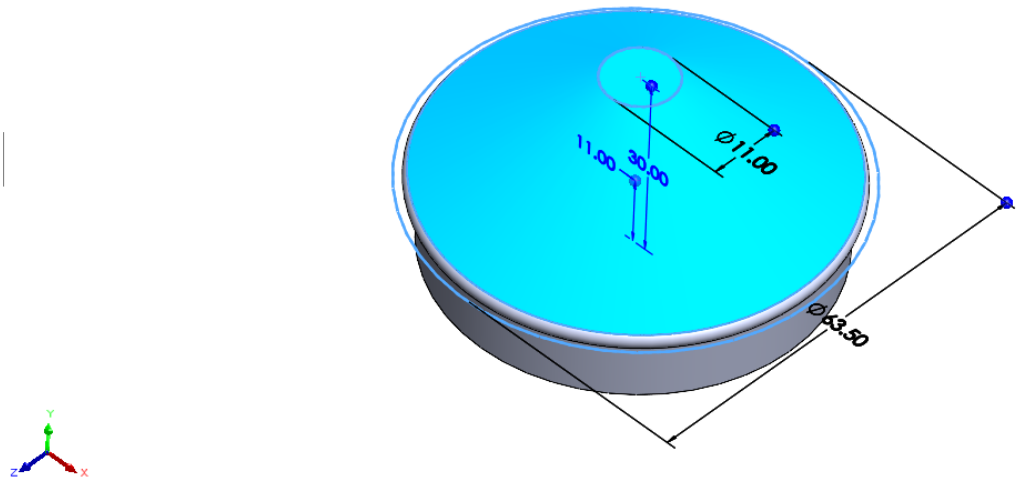

Figure 54. Loft made for the middle conical portion of the teapot lid.

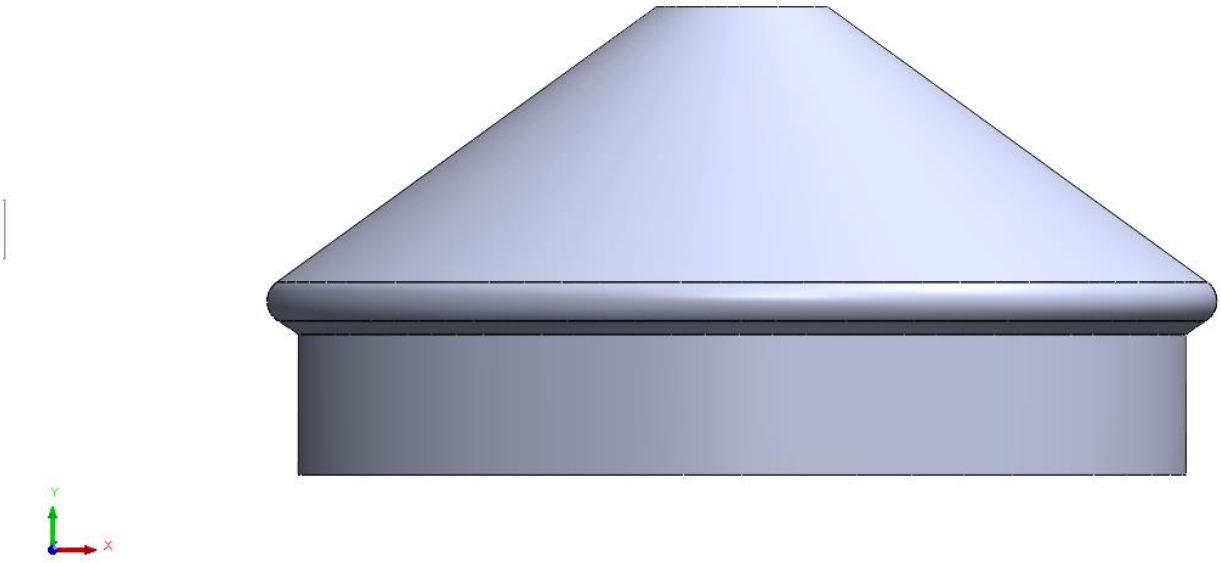

Figure 55. Front view of the filleted middle conical portion of the teapot lid.

After this loft, a 0.5-millimeter shell was made using the bottom face (See Figure 56). The next circular section for the next loft was offset by 0.5 millimeters from the outer edge of the top face of the circular section of the previous loft (See Figure 55). The loft was made using the dimensions shown in Figure 57. The dimension in the y direction is measured from the top face of the circular section of the previous loft. After this step was complete, the appearance of the material was changed to carbon steel within SolidWorks.

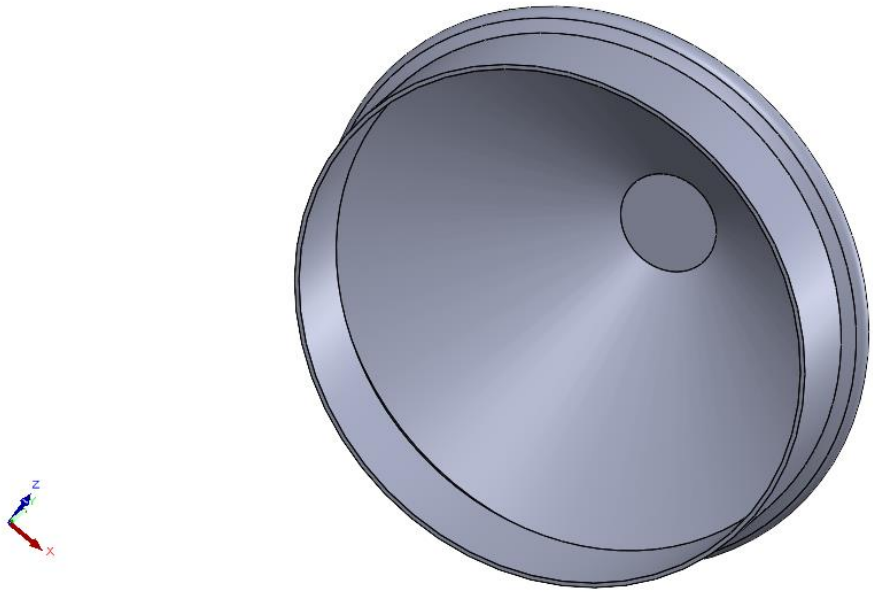

Figure 56. View of the shell feature used on the bottom face of the lid.

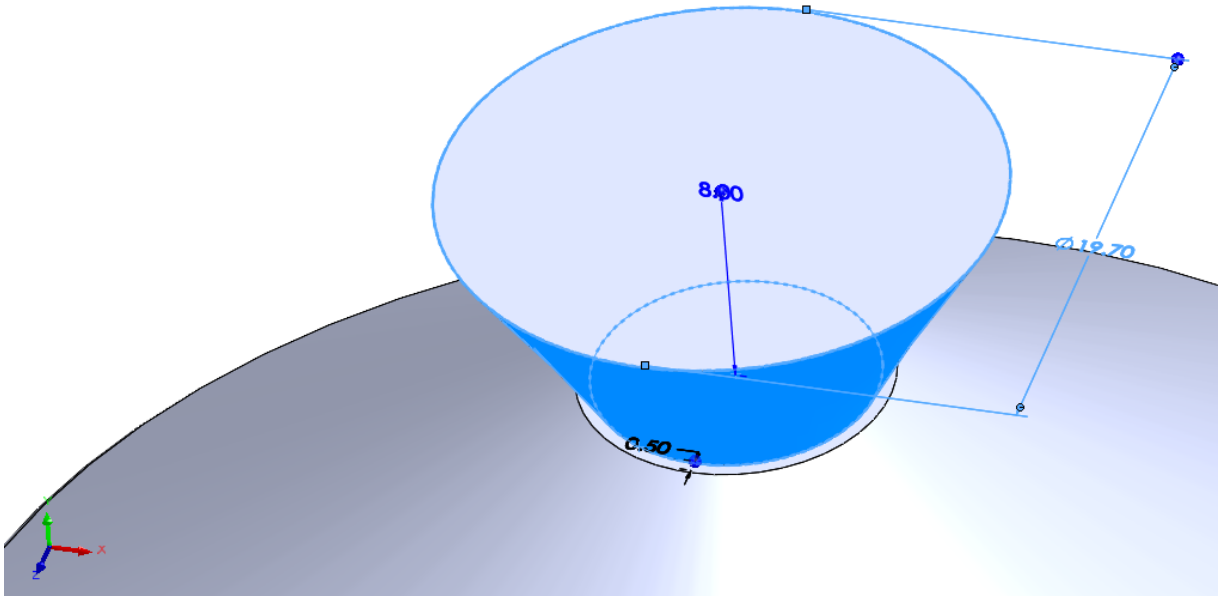

Figure 57. Dimensions used for upper conical section of the teapot lid.

After this step, another loft was made according to the dimensions shown in Figure 58. The center of the 12mm circle is coincident with the larger circular section. The dimension in the y direction (1 mm) is measured from the top face of the circular section of the previous loft.

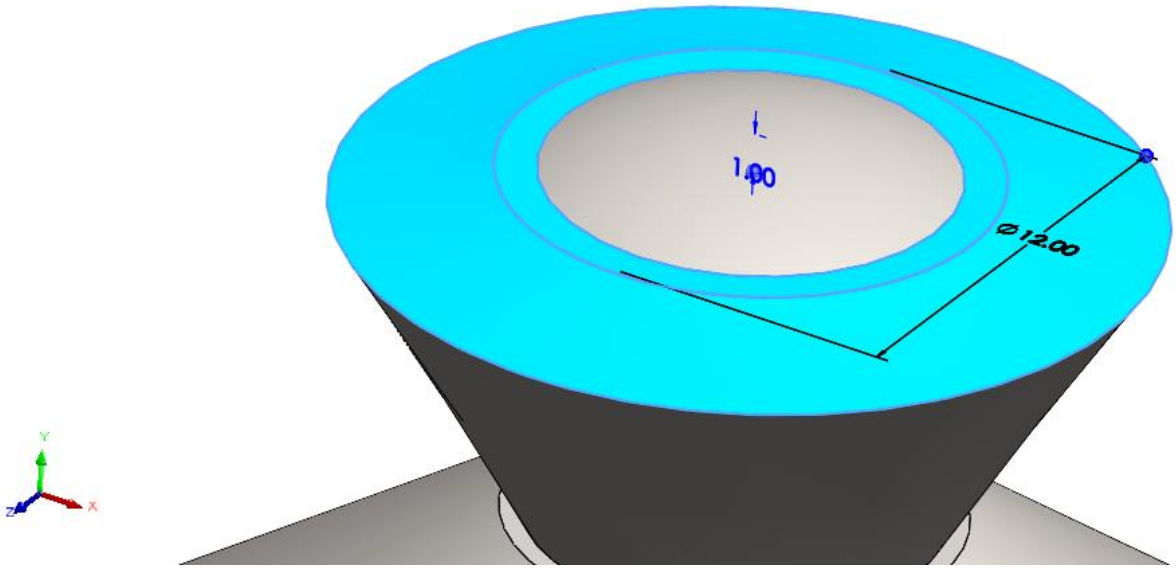

Figure 58. Loft made on top of the loft shown in Figure 57.

Next, a revolve around the y axis was made using the sketch shown below in Figure 59. Initially an arc with a height of one millimeter and a base length of ten mm was constructed. Then, the trimming tool was used to make the sketch shown below.

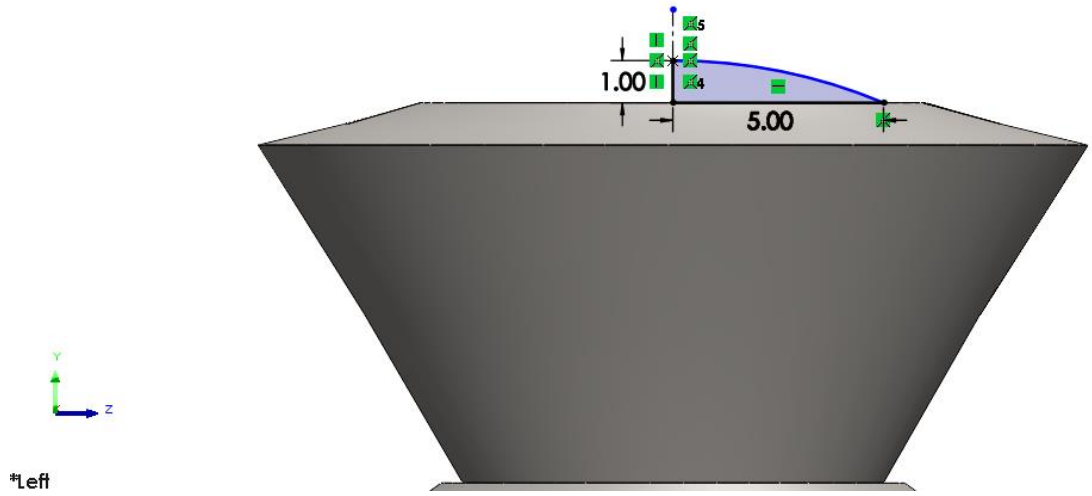

Figure 59. Sketch used to make revolve for uppermost portion of upper conical section of the teapot lid.

Finally, a two-millimeter diameter through hole was made using measurements from Figure 52. This hole allows for steam to pass from the lid of the teapot (See Figures 60 and 61 for a top view and isometric view of the completed lid respectively).

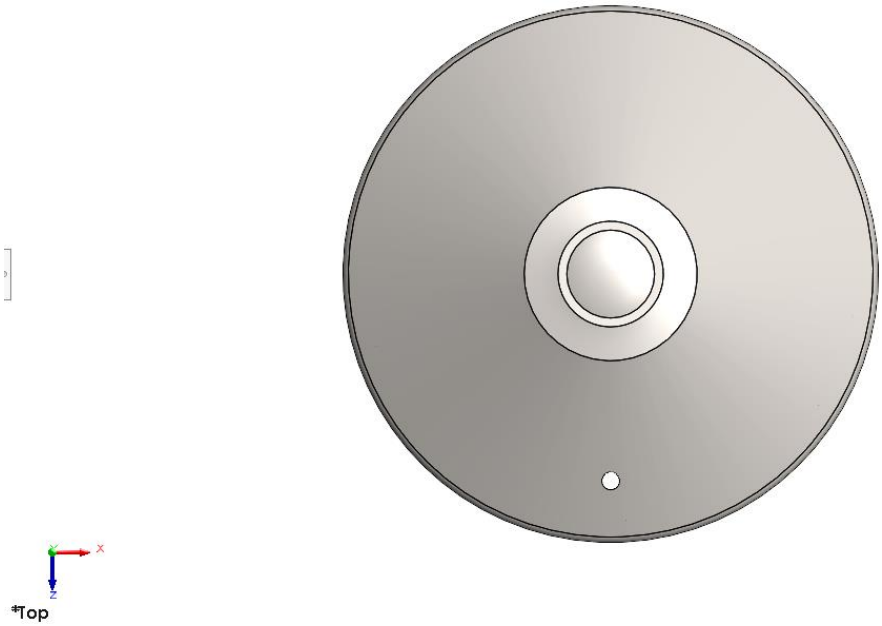

Figure 60. Top view of completed teapot lid.

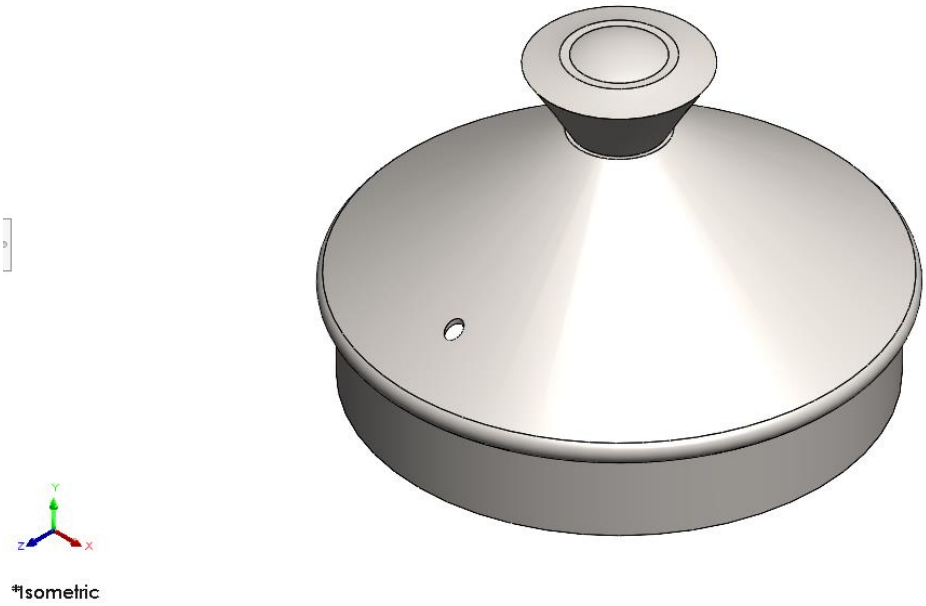

Figure 61. Isometric view of completed teapot lid.

Assembly

Once both the teapot body and lid were modelled, an assembly was created containing both parts. First a concentric mate was made using the lower edge of the lid and the upper edge of the teapot body (See Figure 62). Next, a coincident mate between the upper face of the teapot body and the lower edge of the cap of the teapot lid (See Figure 63). An isometric view of the completed assembly is shown in Figure 64.

Figure 62. Concentric mate made using the lower edge of the lid and the upper edge of the teapot body

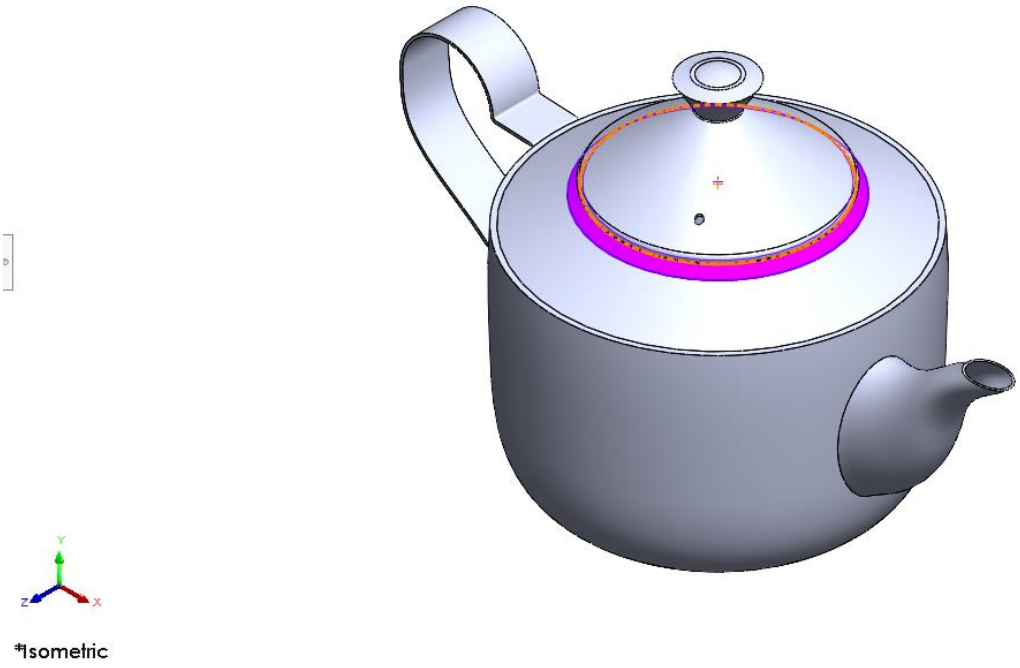

Figure 63. Coincident mate between the upper face of the teapot body and the lower edge of the cap of the teapot lid.

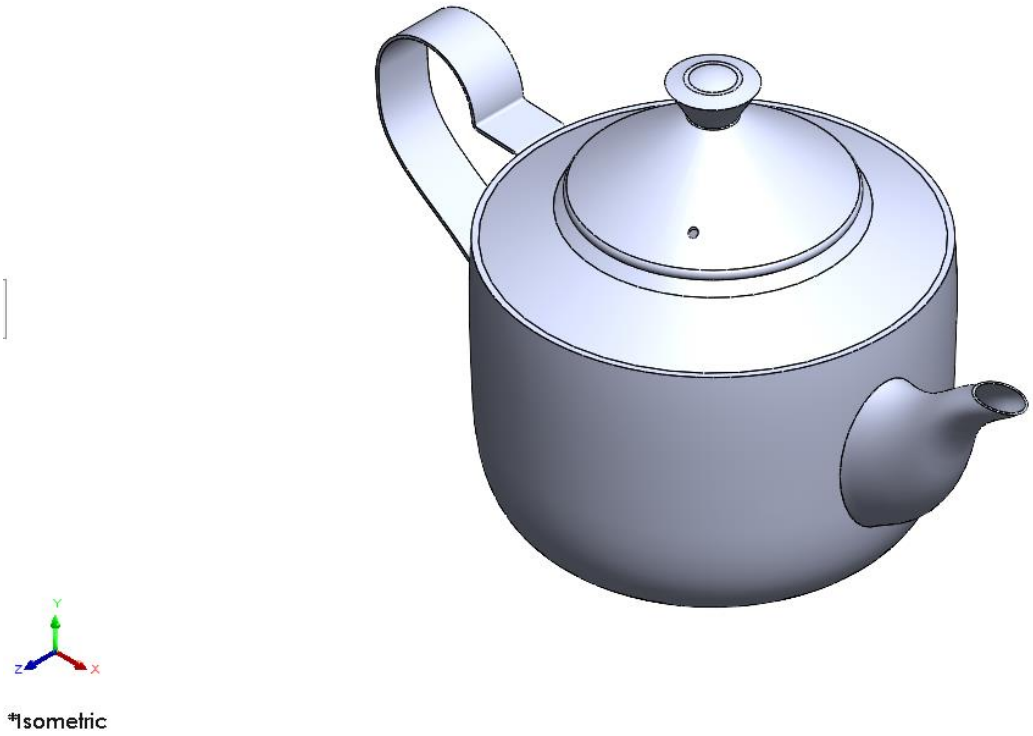

Figure 64. Isometric view of the completed teapot assembly including the teapot body and the teapot lid.

Results

Once the assembly was complete, engineering drawing files were made using SolidWorks for both the teapot body and the teapot lid separately (See Figure 65 and 66 respectively). All units in the drawings are in millimeters, and dimensions for the complex curves are not included. Additionally, dimensions for sketches made using the split curve projected on a surface were unable to be made in the SolidWorks drawings. To see these dimensions, see Figure 9 or 10. If this part were to be fabricated, these parts would likely be manually machined or machined by a computer.

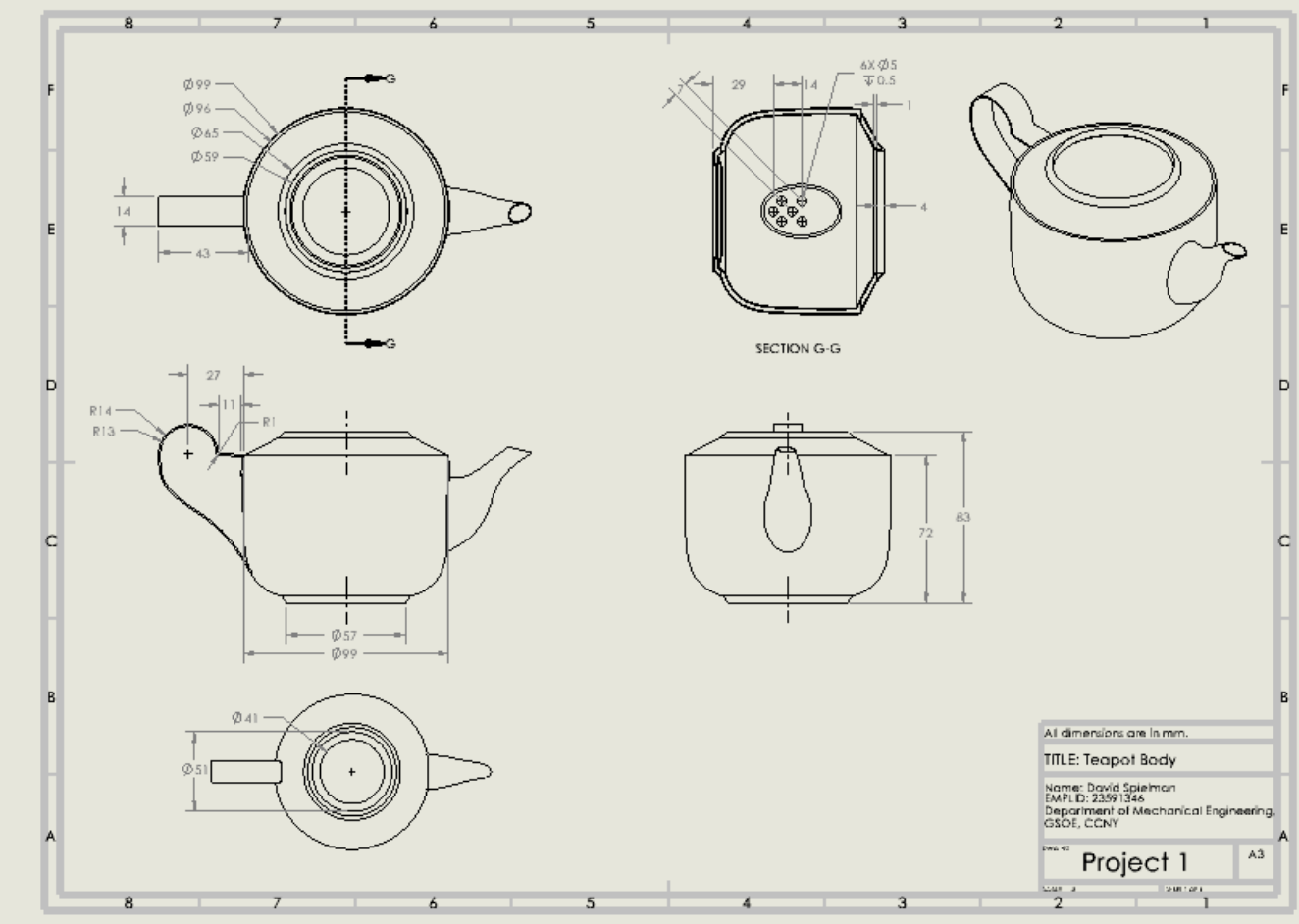

Figure 65. Engineering drawing for teapot body.

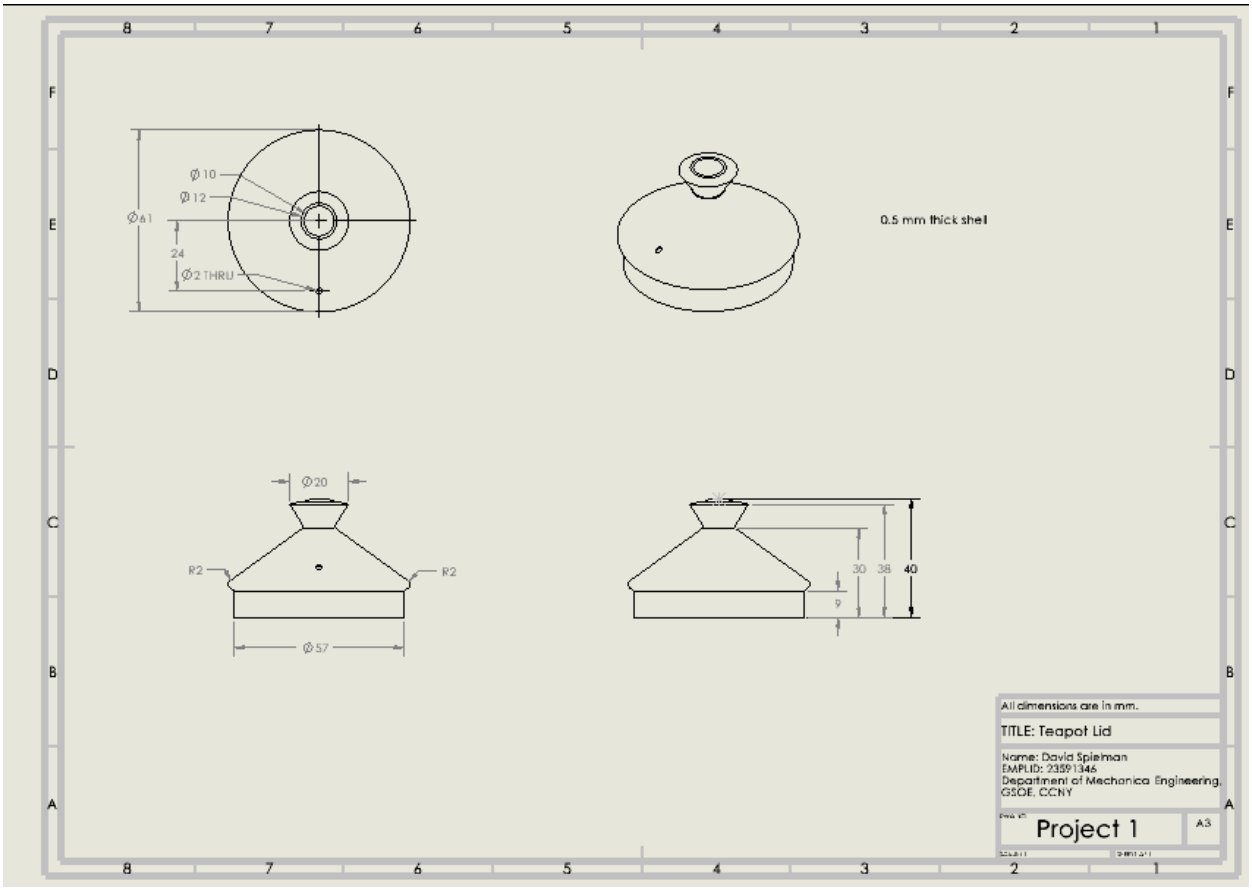

Figure 66. Engineering drawing for teapot lid.

Discussion

The assembly of the teapot turned out well. The measurement methods for most sections of the teapot provided an accurate representation of the real object within SolidWorks. If I had to do this project again, knowing what I now know after completing this project, I would avoid using the sketch picture tool to estimate the curvature of the teapot spout. I encountered many issues with the angle and scale of the images I tried using for reference (as detailed in the modelling section for the teapot spout earlier in the report). Instead, I would employ a similar technique that I used to measure the curvature of the teapot handle. Using a dry erase marker and a ruler to measure vertical and horizontal distances, I would measure various points along the spout and connect them with a sweep to create guide curves for the lofted boss for the spout. This approach may also eliminate the need to create an angled cut since there would be no reference picture, and the measurements for the sweep would terminate along the incline of the angled cut. This would make the modelling of the teapot body more efficient and accurate.

Through this project, I gained confidence using lofts and sweeps in SolidWorks. I also learned a few useful features in the software, most notably the split curve function and the lofted cut function. Measuring the teapot components and documenting the entire design process was also a useful exercise. The skills I developed through working on this project will no doubt be helpful to my development as an engineer.