Engineering Calculus II
Mini Project 1: 3D Modeling

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This project will help you learn how to model 3D objects using SolidWorks and connect the theoretical results we can compute with the tools we have learned about so far with a concrete, tangible object.

SolidWorks is one of the applications available for free to USF students through through the Application Gateway. You do not have to download the program, as you can just run it remotely from the USF servers. When you are done, you can submit an .STL file that can be 3D printed.

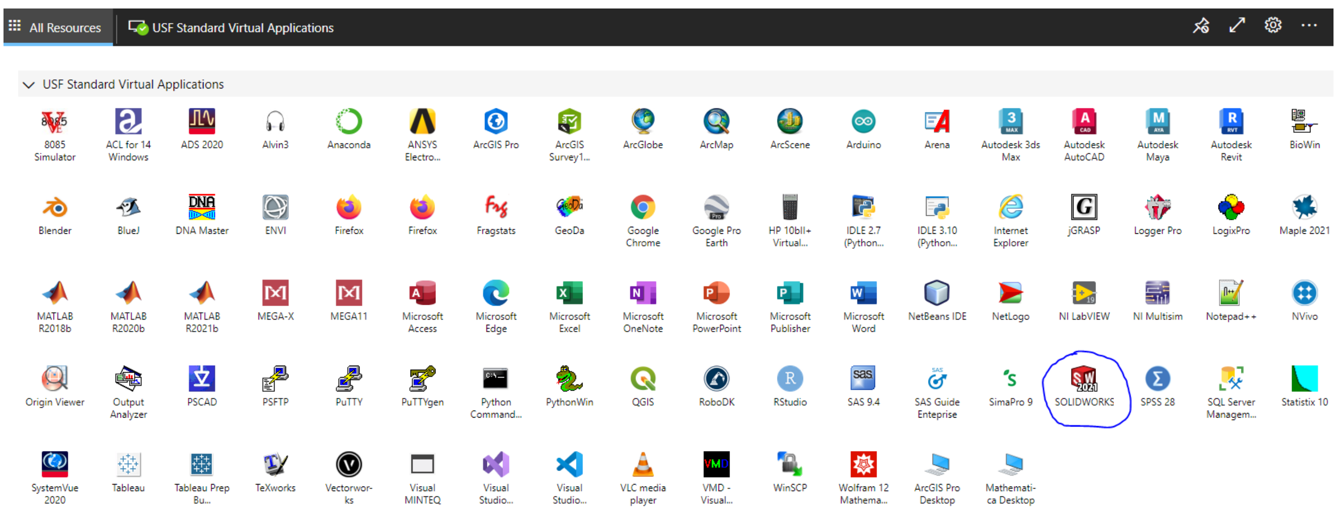

Figure 1: User interface of the remote desktop with applications.

1 Crash Course

While there is plenty of information available online, it can be overwhelming to have so much when you are only trying to do a little. Here are a few tips to get you started. You don't have to use *only* the methods here (for example, there are other ways of filling out the volume of a solid) but anything you do should result in solids like the ones we have learned about in class so far.

1. Set up the units. Go to Options → Document Properties → units to make sure your sketch is made in centimeters.

2. Try out different views. You can click on the views button (see Figure 2) or hover over the views to learn the keyboard shortcuts. The looking glass button on the left will automatically zoom to fit. If you are using a touchpad, avoid gestures that would normally scroll or zoom.

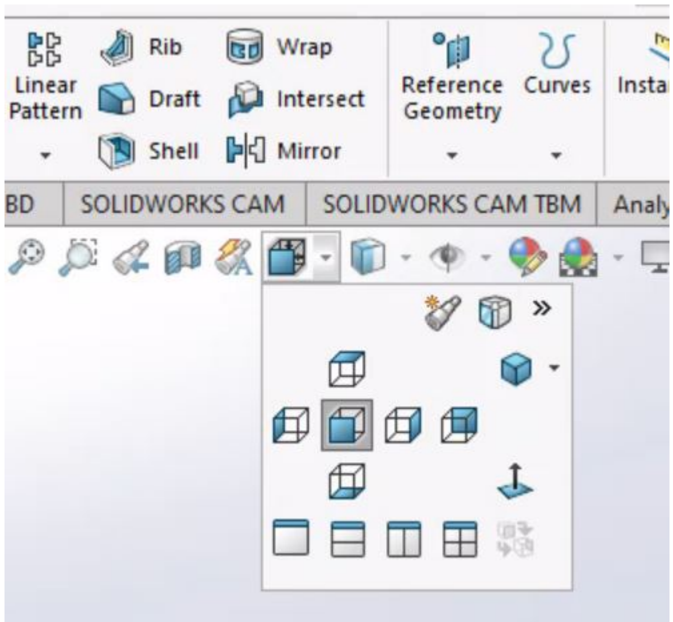

Figure 2: Change the view.

3. To meet project requirements, you will have to use splines: curves defined by equations. Those can be found in the Sketch tab, as shown in Figure 3.

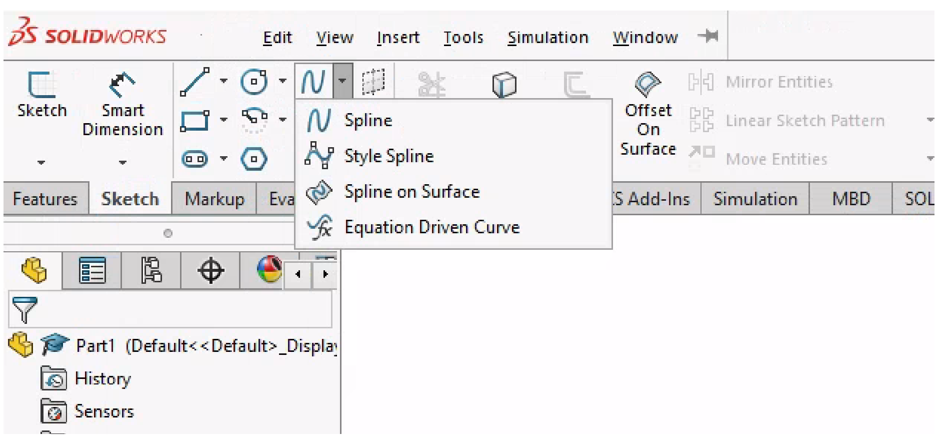

Figure 3: The spline function, in particular splines from equations.

4. You can connect things with straight lines as needed. Those are easy enough to find equations for, so you can just draw them instead of typing in equations.

5. If you sketch multiple things before exiting the sketch, they will all be grouped together. Unless this is what you want, remember to exit the sketches in between different objects.

6. The outline can be filled in to make a solid face. Click on Insert → Surface → fill and then select a closed curve sketch.

7. The main ways to make solids from sketches (that we care about) are revolving and extruding. These are available in the Feature tab a shown in Figure 5 If the Feature tab items appear gray, try clicking on exit

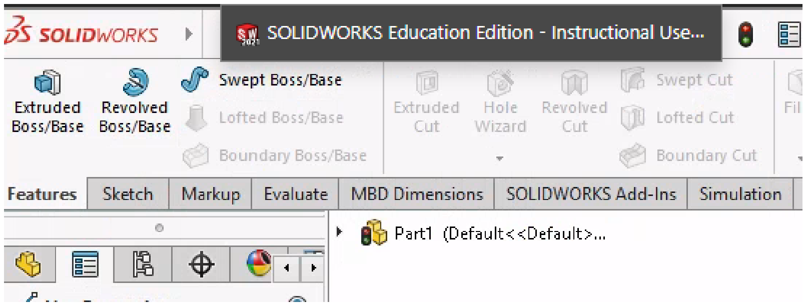

Figure 4: The revolved boss/base and extruded boss/base buttons

sketch from the Sketch tab first.

Both kinds of solids can be made as a hollow surface with finite (but not impossible) width by enabling the Thin Feature option.

Figure 5: The Thin Feature option.

To make the body of your part completely solid inside use Knit (Insert → Surface → Knit). While its usual function is that of stitching together different pieces into one, you can also use it to fill out the cavity enclosed by a surface.

8. To create a revolution solid, click on the closed sketch, then on the Revolved Boss/Base button, then on the line you'd like to revolve about, and finally on the green checkmark on the top left. Note that clicking on the checkmark finalizes whatever you are working on and adds it to the part you are working on.

9. To create an extruded solid, it is easiest to start with a closed sketch, in which case you can just click on the button for Extruded Boss/Base in the Features tab.

   (a) In its simplest form, the extrusion will form a prism out of whatever face you selected, and you can control its length.

   (b) If you look at the options available, you can do much more than that. For example, you can click on the Draft On/Off button to extrude at an angle (see Figure 6).

   (c) You can extrude twice from the same region if you enable the option for Direction 2.

   (d) If you create a solid (for example by revolving or filling a sketch) and then want to extrude from one of its faces, the steps are a bit different. Click on Insert → Surface → Extrude and **hold the `Alt` key** before clicking on the face you want to extrude.

10. **Troubleshooting the USF Application Gateway:** As convenient as it is, it is not without its flaws. If anything crashes or becomes unresponsive, try logging out of your account, deleting cookies and cache from your browser,closing all open browser windows, waiting for about 15min and then starting again.

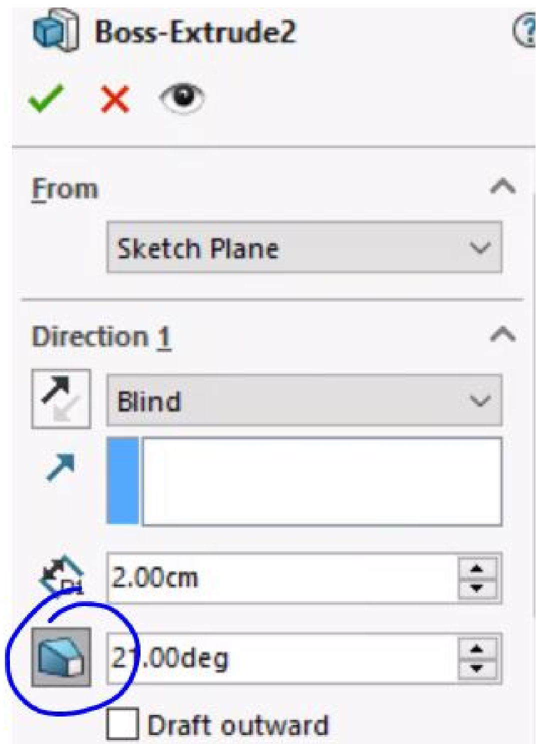

Figure 6: You can control the extruded solid by tapering it in/out and by how much.

It will not be quite as easy as sketching with MS Paint (or equivalent), since we want to be able to model the functions with equations. Though you can glue things together, doing so seamlessly may require algebra (and calculus) work.

You have a week to complete this project. If any of the instructions are not clear, feel free to reach out. Do not wait until the last day. While part of the learning objectives is being able to pick up the new skill independently, ask for help instead of giving up if it seems daunting. The sooner you start, the more opportunities you will have to ask for help if you need it.

Typesetting formulas over the white space may not be easy, so you can print the document after filling all the empty space that needs plain text and hand-write anything that needs mathematical expressions.

A rubric explaining how this will be graded is included at the end of this document.

2 Plan

Since this solid can actually be made, you can start by choosing something practical or meaningful. Your email address will be added to a list so that you can send your file to the USF 3D printing lab without having to pay for it.

Beyond your imagination, your solid will be subject to the following constraints:

- The final volume should not exceed 50cm^3.
- You should use each method to turn a region into a solid (extrude, revolve) at least once on non-constant functions. I.e. your solid should consist of more than the figures we could compute the volume/surface area of using high school geometry. You can use these wherever you need to, but you shouldn't *only* use these.
- It should be possible to compute properties of the solid (volume, surface area) with only the tools we have

learned about in class so far. This limits the kinds of functions you can use, especially when it comes to computing surface area.

With this in mind, let's do some prep work.

Explain the steps you would follow to compute (or approximate) the volume and outer surface area of a solid S obtained through the following procedures. Make sure to include any formulas you would use.

1. extruding a region R bounded by $f(x)$, $g(x)$, $x = a$, $x = b$

2. revolving a region R bounded by $f(x)$, $g(x)$, $x = a$, $x = b$ about a vertical or horizontal line.

3. a hollowed out version of the solids described above

3 Design

Make a couple of sketches of the object you are trying to create. Depending on the object, it would be helpful to include cross-sections, a side/top/front view, and a rough estimate for the dimensions. If needed, you can insert more pages here. Just make sure your diagrams are clear/easy to understand. Pretend you are giving these out for someone else to produce and add notes of anything you'd like them to consider. Drawing in 3D is hard, this is why we're using SolidWorks for the rest, but we need to start somewhere.

Sketch here

Break down your object into pieces, and explain how each piece would be created. Will it be a revolution solid? An extruded solid? A draft? What functions[1] could you use to model it?

You can enumerate, label, color-code, or distinguish the pieces any way you like. For each piece, include

1. A sketch
2. A method to create it in SolidWorks
3. A list of functions types (quadratic, cubic, trigonometric, exponential, etc.) you can use to obtain the desired result. Make sure to include at least 3 per piece and no less than 5 different function types altogether (combining the functions from all pieces).

Individual pieces

[1]It really should be functions, plural. As you'll see in the next few steps, some of these won't work great in the integrals we can compute at the moment.

4 Constraints

Make a comprehensive list of the functions above, we'll want a centralized database for the step that follows. Many of the functions we are familiar with will not work nicely in the volume and surface area formulas we can work with, so we should rule any of those out before proceeding. It is at this step that you may have to get creative coming up with new functions if all of the ones you had above caused trouble. Note that you don't have to use the exact function formula, just a simple version of its function type.

You can fill out the table that is in the next page

Function	Creation method	Volume	Surface area	Notes
$\sqrt{1-x^2}$	revolution solid	$V = \int_a^b \pi(1-x^2)dx$	$S = \int_a^b 2\pi x\sqrt{1+\frac{x^2}{1-x^2}}dx$	Using disks for the volume. The surface area integral can be evaluated with substitution.

Where you decide in the notes that the volume and surface area for a particular function type can, indeed, be computed, show why with an example using general constants a, b, c etc. Include the work.

5 Plan again

Through trial and error (and with the help of any online tools like WolframAlpha or GeoGebra) choose functions you can integrate volumes and surface areas for and use graph transformations to replicate your sketch. Include a graph (these can be computer generated) of the resulting functions with appropriate domain restrictions making sure that the function formulas appear in full.

Here is where we compute the actual volume and outer surface area of the solid. Computing these values exactly after making the above adjustments can be cumbersome, so you can use any tools you like for your approximation as long as you show your work (what you typed and where).

Sketch made of functions goes here

6 Make the solid

Make sure to adjust the unit settings on SolidWorks to centimeters. You can use the volume estimates provided by the program to check your work. Include some pictures of the work you did (for example including equations and cross-section sketches).

Screenshots can go here

Save your file as an .STL . From the Application Gateway, the easiest way will be to save to OneDrive (especially because the files may be pretty large). You can then share these with me (rather than attach them to an email or upload them to Canvas). When your design is approved, you can put in an order to have it 3D printed.

Mini Project 1: 3D Modeling
Rubric

	1	2	3	4	5
Calculus concepts	Lots of work missing/incorrect/requires more advanced tools	Some work missing/incorrect/requires more advanced tools.	About half of the work is complete and correct.	Most explanations are complete and correct, using only the tools learned so far.	All explanations are complete and correct, using only the tools learned so far.
Math work (worth double)	Many solutions are incorrect or incomplete	A few solutions are incorrect or incomplete	Some solutions are missing steps or have small errors	A few solutions are missing steps or have small errors	All solutions are correct and complete
Clarity	It is hard to read/follow the work	Some of the work is hard to read/follow	The organization/tidiness leaves room for improvement but is readable	The work is generally easy to read/follow	It is very easy to read/follow the work done
Program use	No evidence of SolidWorks being used	SolidWorks used but not clear how	Some instructional value in the screenshots	A couple steps are left to the imagination but overall clear	The work can be reproduced exactly from the pictures
Final solid	.STL file not submitted	.STL file doesn't meet requirements or doesn't agree with the work submitted.	Some of the aspects of the solid weren't clear from the work submitted and the volume/surface area predicted disagrees with calculations.	Some of the aspects of the solid weren't clear from the work submitted but predictions agree with calculations.	Solid is well described in work and all predictions agree with calculations.