Poké Ball

Keertik Bacon

Section F

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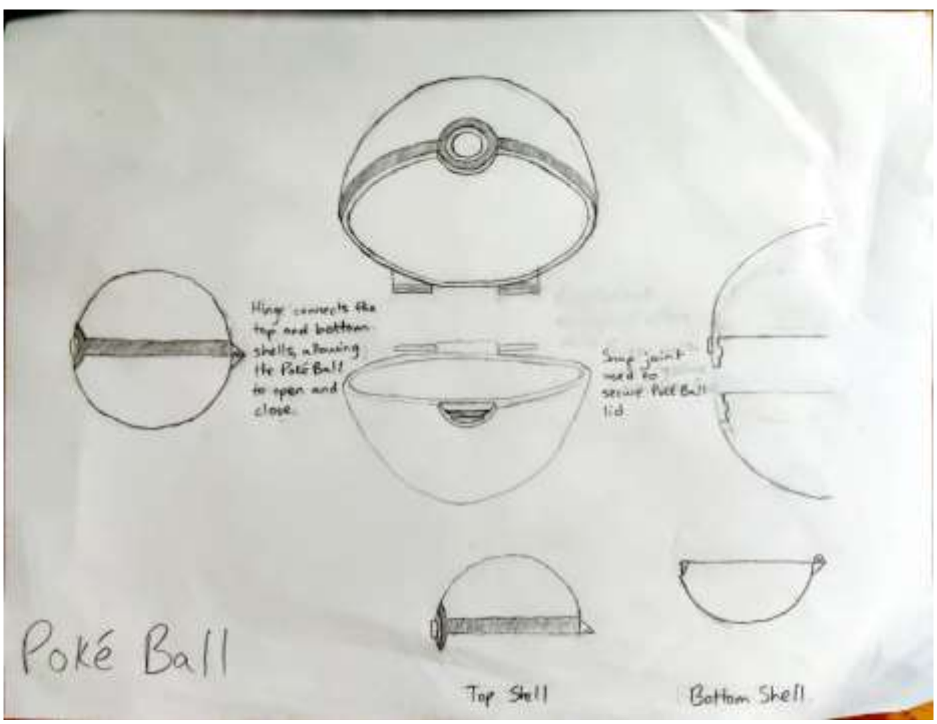
Project Description

For this project, I modeled a Poké Ball, the hinged creature storage device from Pokémon. I played some of the Pokémon video games when I was younger, and so when I received the brief of designing a small object with interlocking features, one of my first ideas was to design a real-life version of the Poké Ball. Of course, I can't replicate the creature-capturing functionality, so I decided to design it as a small storage box instead.

The Poké Ball, as depicted in the Pokémon video games and TV show, doesn't explicitly show any interlocking features. We infer the existence of a hinge based on how the top and bottom shells pivot, and so while I modeled the general shape of the ball off of the official design, I made my own interlocking features. I designed a hinge at the rear of the Poké Ball to allow it to open and close, and I also added a snap fit at the front of the ball, concealed below the "button," so that the Poké Ball snaps shut and only opens when the user opens it. I made an effort to integrate my additions smoothly with the existing design, as I did not want to call too much attention to the interlocking features.

Below are the original design sketches that I submitted for approval for the project.

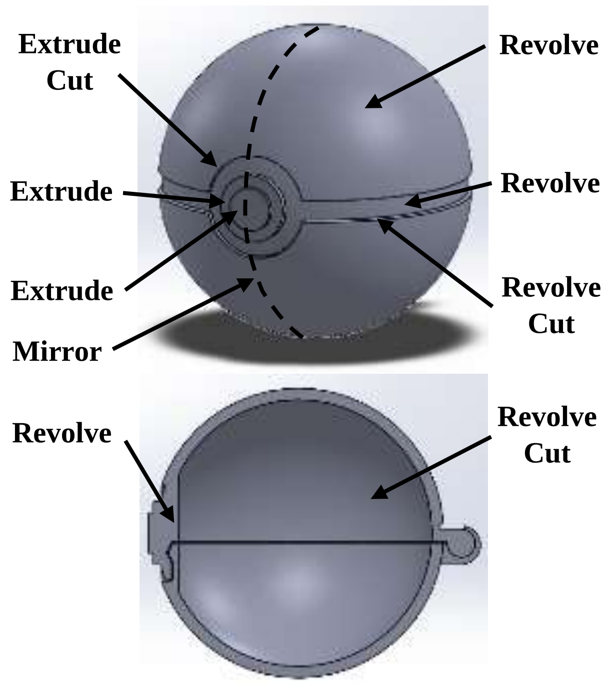


CAD Features

Both halves of the Poké Ball were modeled together before being split into two parts. Because of this, I will list the common features of both shells, before going into their individual features.

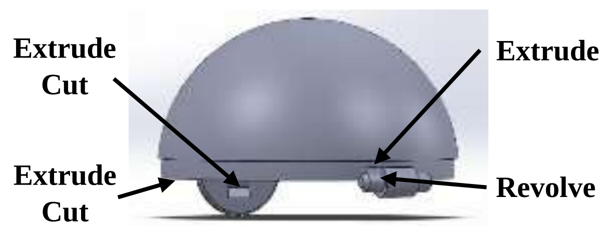
Common Features

- **Revolve:** Outer shell layer
- **Revolve cut:** Cut out center stripe
- **Extrude cut:** Cut out circle surrounding button
- **Revolve:** Fill in the inner layer
- **Extrude:** Button surrounding ring
- **Extrude:** Button
- **Revolve cut:** Hollow out inside
- **Revolve:** Interior extra thickness
- **Mirror:** Left half of Poké Ball mirrored



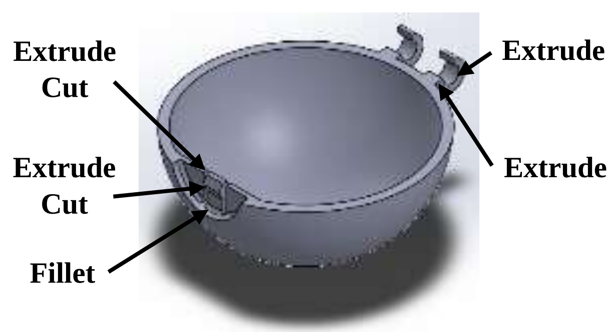
Top Shell Exclusive Features

- **Extrude cut:** Snap-fit slot
- **Revolve:** Hinge shaft
- **Extrude:** Hinge shaft to body connection
- **Extrude cut:** Removing some material along the bottom for tolerance purposes



Bottom Shell Exclusive Features

- **Extrude cut:** Making a gap to shape the snap-fit connector
- **Extrude:** The protruding edge of the snap-fit connector
- **Fillet:** Round bottom of snap-fit connector for strength
- **Extrude:** Hinge clamp
- **Extrude:** Hinge clamp to body connection



Interlocking Features

- **Hinge:** The top and bottom shell are connected at the back by a hinge, allowing the device to open and close

- **Snap-fit:** The front side of the bottom shell has a snap-fit arm connector that connects to a groove on the top shell; the snap-fit is reversible, to allow the Poké Ball to snap closed and not fall open at undesired times

Design for Manufacturing Considerations

After doing some research on the size of a Poké Ball, I found that it was roughly the size of baseball, around 2.5 – 3 inches in diameter. Wary of the 3 x 3 x 3 bounding box limit allotted to me in the 3D printer, I initially went with a 2.5 in. diameter, but I soon found out that this made a lot of the smaller features, namely the snap-fit connector, too small. So, I increased the diameter to 3 inches, but this meant I had to be careful with the size of the hinge, which extends out of the 3 in. diameter. I solved this problem by orienting the ball in the bounding box such that the center axis of the ball, going from the button on the front to the hinge in the back, goes along the diagonal of the cube, giving me around 5 inches to work with in that direction.

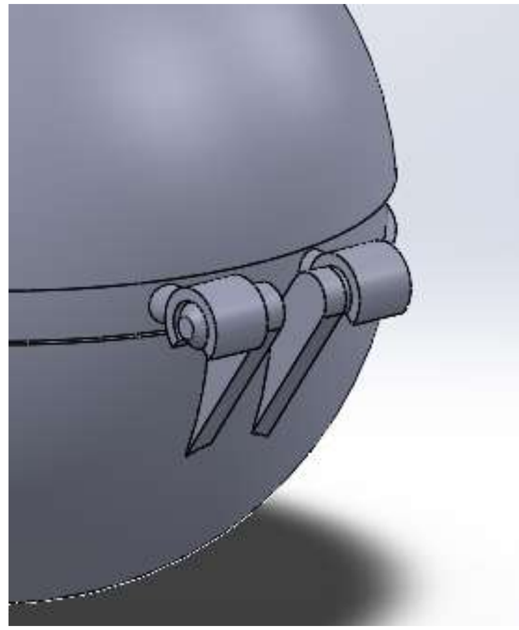
The choice of interlocking features was determined with the product's intended functionality. As the Poké Ball hinges open in the Pokémon video games and TV show, I chose to add a hinge to the back of my design, so that it can open in much the same way. The snap fit was added because of my idea of using my Poké Ball as a small storage chest. I didn't want the Poké Ball to tip over and immediately have the contents fall out, so I added the snap fit to ensure that the Poké Ball would stay shut unless opened by the user.

Because my Poké Ball consisted of two parts that moved past each other, I used a moving tolerance of 0.016 in (0.4 mm) wherever the two parts met, including the hinge, snap fit, and the face on the bottom of the top shell and on top of the bottom shell where the two halves contacted.

Both of the interlocking features went through a few design iterations, to iron out any potential issues, as well as to improve appearance. These iterations are detailed below.

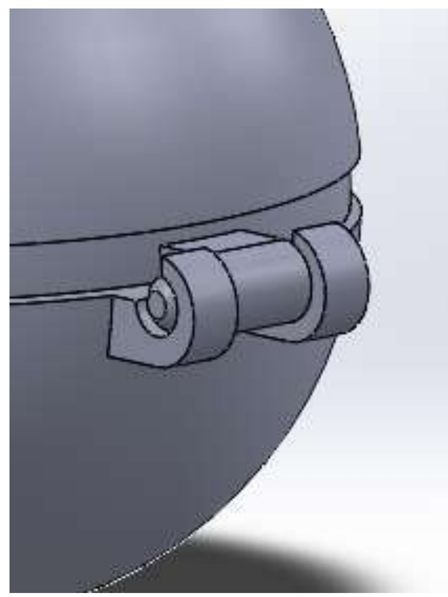
Hinge Design Evolution

Iteration 1



- Hinge clamps extend from the top shell, while the shafts extend from the bottom shell
- Problems
  - The attachment between the shafts and the bottom shell is excessively large
    - Contributed to the original version of the Poké Ball being 0.5 in^3 over the 4 in^3 volume limit
  - The clamps don't seem well integrated with the Poké Ball body, rather appearing tacked on

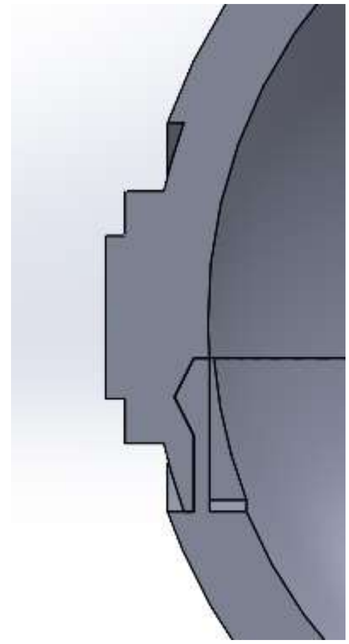
Iteration 2 (final)



- Pivot point is moved down to the plane of the boundary between the top of bottom shells, to be more accurate to the canonical Poké Ball
- Shaft is redesigned to extend straight out of the ball, rather than extending at an angle, saving volume
- Clamps are better integrated with the Poké Ball body
  - The clamps had to be moved to the bottom shell and the shaft to the top shell, as the new clamps were too tall to fit in the ridge in the middle of the ball

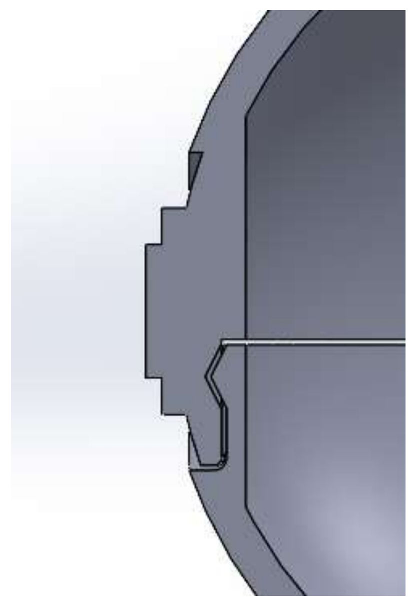
Snap-fit Design Evolution

Iteration 1



- Snap-fit connector and slot are essentially “cut out” of the interior thickness of the Poké Ball
- Problems
    - The Poké Ball had to have a large thickness (0.19 in) to accommodate snap-fit connector
        - Contributed to the original version of the Poké Ball being 0.5 in^3 over the 4 in^3 volume limit
    - The top shell ends up really thin near the bottom of the connector area, potentially causing printing problems
    - It’s not a very elegant-looking solution, due to how we cut out material behind the connector

Iteration 2 (final)



- Rather than increasing the thickness of the entire shell, only the thickness of the front portion is increased
    - This allows us to decrease the overall Poké Ball thickness to 0.12 in
    - We can also add enough thickness to ensure the bottom edge of the top shell is not too thin
- No more inelegant cutting out material behind the snap-fit connector as well
- Fillet was also added to the bottom of the connector, to reduce stress concentration

Challenges Faced in Manufacturing

The parts were printed on a high-end SLS printer, and so manufacturing defects, if any, were negligible. Before submitting my CAD files, I made sure to check that all my features were of adequate size for the 3D printer to print properly, and so all my parts were printed as they should have been.

However, upon assembling the Poké Ball, I discovered that the parts were too loose. The hinge shaft rattled around in the clamp, and the top and bottom shells slid past each other. The snap fit would not hold the Poké Ball closed. Evidently, I had made the tolerances too loose.

I realized that I had applied double the tolerance that I was supposed to, due to misinterpreting the tolerance value. A sliding tolerance of 0.016 in. means that the diameter of the shaft must be 0.016 in. smaller than the diameter of the hole, but I mistakenly interpreted it to mean that there must be 0.016 in. between the edge of the shaft and the edge of the hole when the shaft is in the hole. As a result, I was subtracting 0.016 in. from the radius of the shaft instead of the diameter, making my tolerances twice as large as they were supposed to be.

The solution for this problem would be to halve the tolerances that I had applied on the hinge shaft, snap fit, and the circular button section on the top shell. Luckily, I learned this lesson early on, rather than on a project in a future class in which the wrong tolerances would have been more consequential.

Tolerance Analysis

Feature	**Dimension in CAD**	**Actual Measured on 3D part**	**% difference**
Center Stripe Diameter	2.920 in	2.890 in	1.03%
Inner Diameter	2.760 in	2.760 in	0%
Shell Thickness	0.120 in	0.120 in	0%
Hinge Shaft Diameter	0.193 in	0.201 in	4.06%
Hinge Clamp Inner Diameter	0.226 in	0.227 in	0.44%
Center Stripe Thickness	0.080 in	0.073 in	9.15%
Button Diameter	0.420 in	0.417 in	0.72%
Button Ring Diameter	0.650 in	0.653 in	0.46%
Ball Diameter	3.000 in	2.994 in	0.20%
Button Section Thickness	0.238 in	0.243 in	2.08%

The physical part's dimensions are quite accurate to those of the CAD model. As seen in the table above, the largest discrepancy in size is only 0.03 inches, in the diameter of the center stripe section. Percentage-wise, although the 9.15% difference seen with the thickness of the center stripe section might appear quite large, it is inflated by the small size of the feature, with the actual discrepancy being only 0.007 inches.

Looking at the data, there aren't very many strong patterns regarding which dimensions are larger in the physical product than in the CAD model, and which are smaller. Out of the 10 dimensions that I've collected in the physical product, 4 are larger, 4 are smaller, and 2 are equal to the dimensions in the CAD model. Even looking at just the outer diameters and thicknesses, of which there are 8 measured, 4 are too small, 3 are too large, and 1 is the right size. Similarly, with inner diameters and other slots, of which there are 2 measured, 1 is too large, and 1 is the right size. This dataset is too small to form any conclusions, but it does seem like that, barring any physical measurement error on my part, there are no patterns on a certain type of feature being consistently too large or too small.

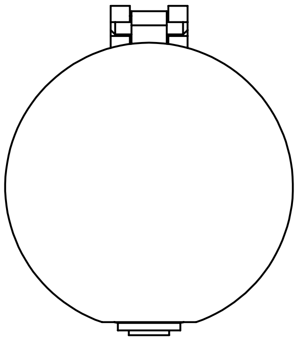
Final Design and Conclusions

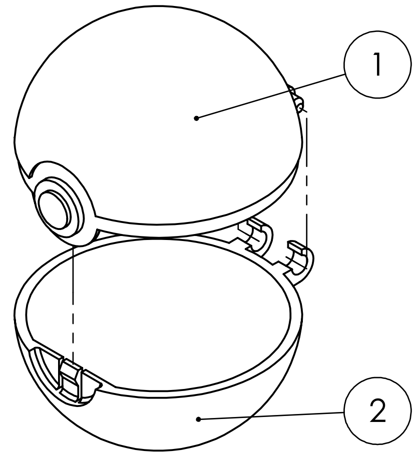
Since my product was inspired by the already existing Poké Ball design, most of the product remained the same throughout the design process. The only design change involving the entire product was its scale, as I experimented with a 2.5-inch and 3-inch overall diameter, before settling on 3 inches. Nearly all of the iteration involved my original additions to the design, namely the two sets of interlocking features. As I detailed in the "Design for Manufacturing Considerations" section, my iterations on the snap fit and hinge mainly involved reducing volume and making the design more elegant.

Even if I did not explicitly learn something new through this project, I did develop some design habits. For example, I began drawing out my ideas before building them in CAD. When I was trying to improve on the snap fit and hinge, I filled a sheet of paper with different ideas and rough sketches, before finally settling on the designs I liked and creating them in SolidWorks. Through repeated trial and error, I also gained a better intuition of which feature operations work best for which kinds of features. Even though I learned about all the operations in class, it was through this project that I better understood how to model certain features. All in all, the difficulties I faced in this project ultimately made me a better CAD designer.

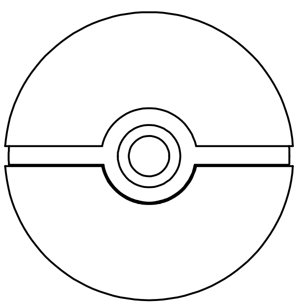
CAD Drawings

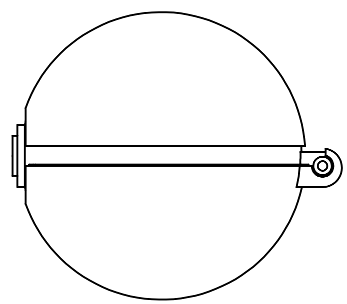
The next 3 pages contain all the engineering drawings for my final Poké Ball design.





ITEM NO.	PART NUMBER	QTY.
1	Top Shell	1
2	Bottom Shell	1





Georgia Institute of Technology

TITLE		DATE	NAME			
POKÉ BALL		4/23/2021	KEERTIK BACON			
COURSE	SEMESTER	SECTION	LAB	ACTIVITY	DIMENSIONS ARE IN INCHES ANGLES ARE IN DEGREES	SIZE
ME 1770	SPRING 2021	F			SCALE 1:2 SHEET 1 OF 1	A

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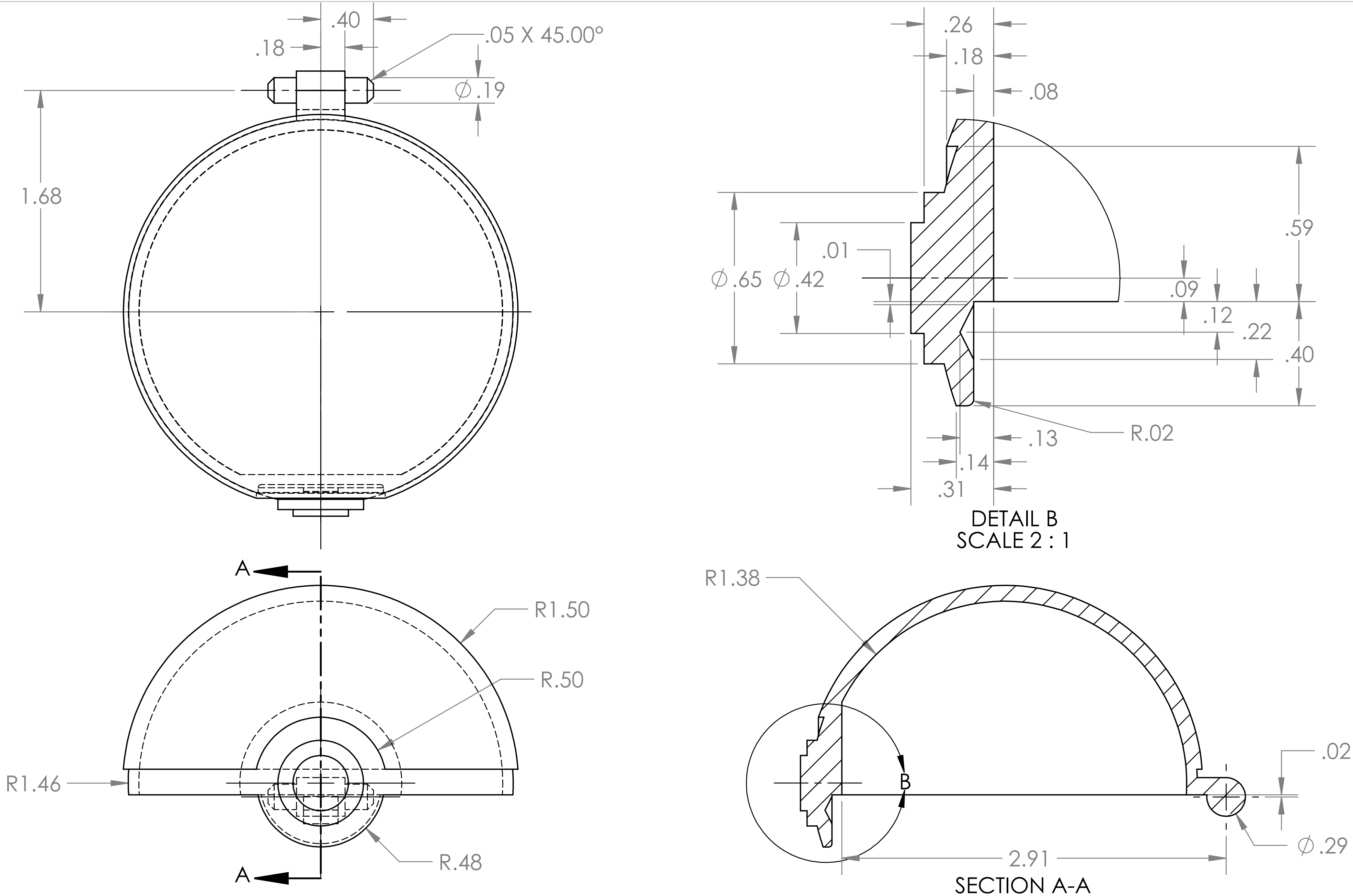

Georgia Institute of Technology	TITLE **TOP SHELL**		DATE **4/23/2021**	NAME **KEERTIK BACON**			
	COURSE **ME 1770**	SEMESTER **SPRING 2021**	SECTION **F**	LAB	ACTIVITY	DIMENSIONS ARE IN INCHES ANGLES ARE IN DEGREES SCALE 1:1 | SHEET 1 OF 1	SIZE **A**

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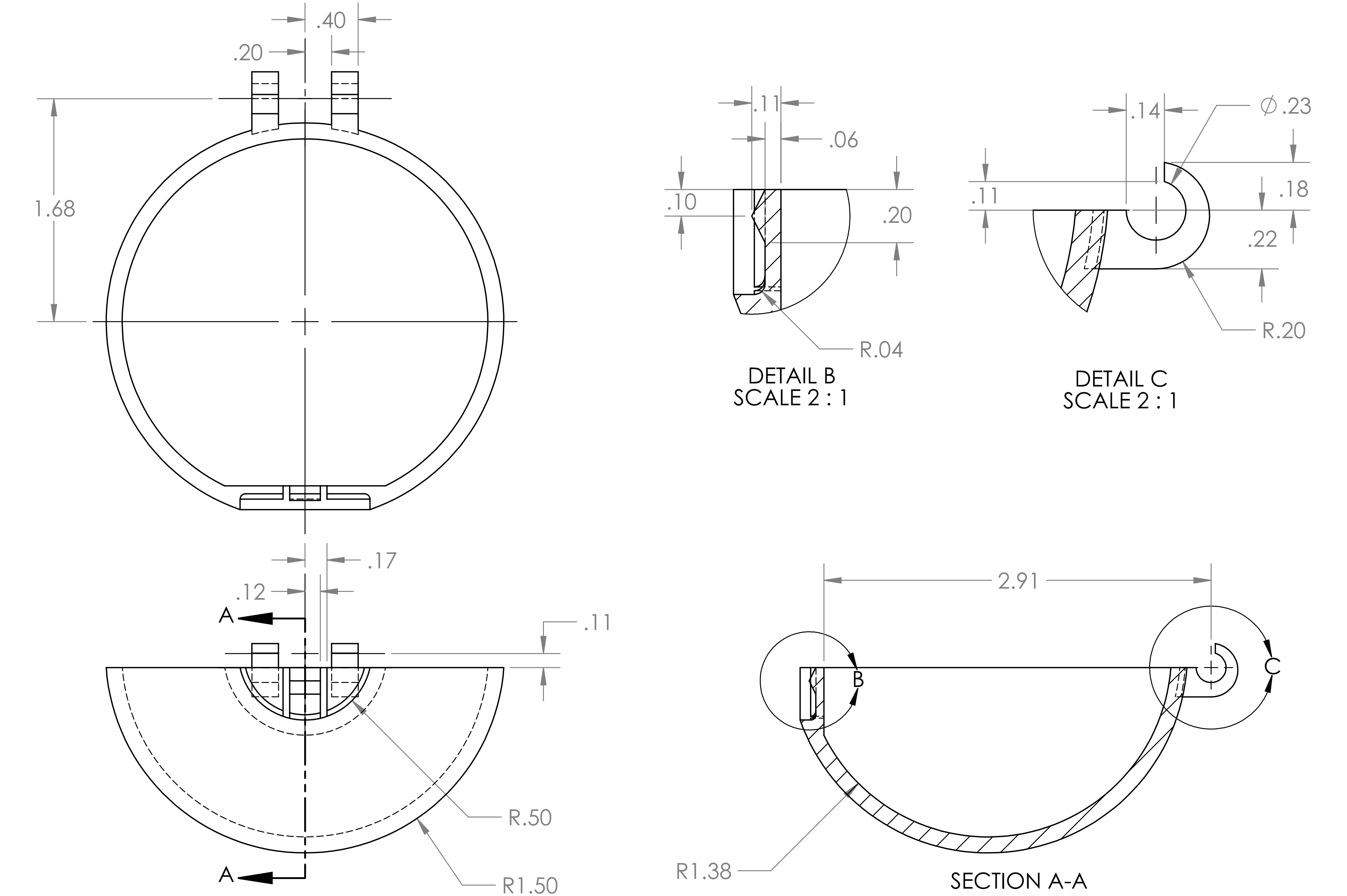

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