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MEMS 411: T-SHIRT STRIP DISPENSER

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Mechanical Engineering Design Project
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T-SHIRT STRIP DISPENSER

In this project, our group worked towards making a fabric dispenser for Professor Mary Ruppert-Stroescu of the Sam Fox Fashion Design School. She as well as others from the Sam Fox school are taking old, used fabric, cutting it into half inch wide strips, and using said strips to design and make new clothes. However, all of the strips used in this program are being applied by hand currently. We aimed to create a dispensing device similar to a tape gun to expedite the process of laying out the strips. We first made a mockup of the product based on similar existing devices such as tape guns and 3D printers. From there we were able to see what aspects of our mockup would be easy to make and which ones seemed like they would not work well for the intended client. We knew that this device had to light weight and simple to use, and so we figured basing our design as closely to a tape gun as possible would provide the most intuitive product for the client. We also decide to 3D print our device as that would allow for the greatest flexibility in the designing process as well as keep the device light. In the end our product was functional but not very effective. If given the time to make a third prototype then we could have made something much better.

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1 Introduction

The T-shirt Strip Dispenser Project aims to make a device that unspools strips of T-shirt material onto a flat surface. It requires a precise dispenser to minimize the friction between strips and machines, because the plastic deformation of strips will happen even a slight pressure or stretch applied on them during the process. It also needs to account for an adhesive and other desired user procedures, so the strips can attach to the desired canvas. The dispenser should function by easily turning after each line of strip is applied, and to apply multiple lines of strips and angles at the same time depending on a user's goals, thus making the process more efficient and create different patterns.

2 Problem Understanding

2.1 Existing Devices

There currently is not exact device that does what the project aims to achieve. Rather, this subsection will show different devices that we can and will use as inspiration when designing our T-shirt strip dispenser.

2.1.1 Existing Device #1: Tape Gun

Figure 1: Scotch® Low Noise Tape Dispenser H150 (Source: 3m.com)

Link: https://www.3m.com/3M/en_US/p/d/b40069553/
Description: This tape gun is made from lightweight metals for easy handling and control and operates smoothly and quietly [1]. We can design this project on a smaller, simpler scale by basing

our dispenser off of this device. Since this project aims to make an apparatus that dispenses fabric wrapped around a spool, then a tape gun such as this is a fantastic base model.

2.1.2 Existing Device #2: 3-D Printer Chassis

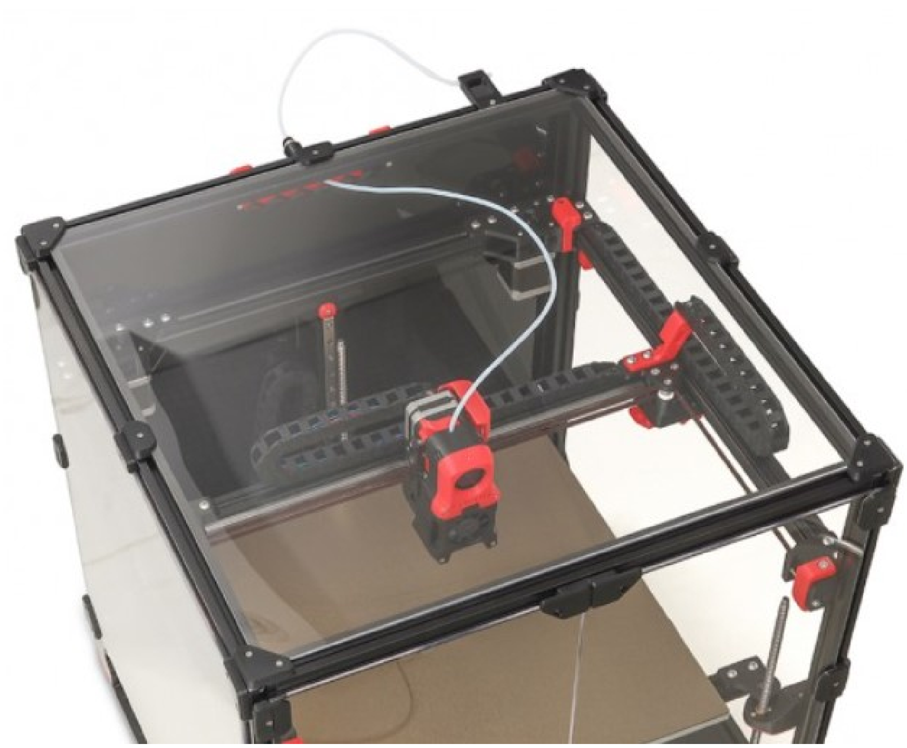


Figure 2: Formbot Voron Trident R1 CoreXY 3D Printer Kit (Source: 3dprintersbay.com)

Link: https://www.3dprintersbay.com/voron-trident?srsltid=AdGWZVSJBeJrMipgsCfZ4aD_vge2FeTY98V-WGVM2pT1zWkeQmjdXccX_to

Description: If we wish to move this project to a larger scale, then creating a 2-D movement system similar to the one on the 3-D printer shown in Figure 2 would allow us to potential make the system autonomous. Even just a chassis system of wheels on tracks and having someone move the spool manually could help in speeding up application of the strips. Such a system, like with the tape gun, would need to be light and, in the case of this chassis, maybe could be made collapsible.

2.1.3 Existing Device #3: Ticket Dispenser

Figure 3: Garvey® My Turn Ticket Dispenser (Source: staples.com)

Link: https://www.staples.com/Garvey-My-Turn-Ticket-Dispenser-Black-Red-TAGS-12001/product_1670037
Description: Simple to use and lightweight, we could design a wider version of this to fit multiple spools of fabric. We could also attach wheels to a similar dispenser to move along the sheet the strips would be stuck to. The only concern of rolling wheels along an adhesive is that it may degrade the quality of the adhesive when it comes to sticking to the strips.

2.2 Patents

2.2.1 Tape Dispenser with Handle (USD854616S1)

The patent is a tape dispenser with a handle. It has a shell that is further extended to serve as a handle, at least one fixing device for holding the tape, a transfer roller connected to the shell, and a cutter assembly connected to the shell. The tape cutter can easily cut tape, the transfer roller can rotate with the tape, and the fixed device can adjust the radius to fit tapes of various sizes.

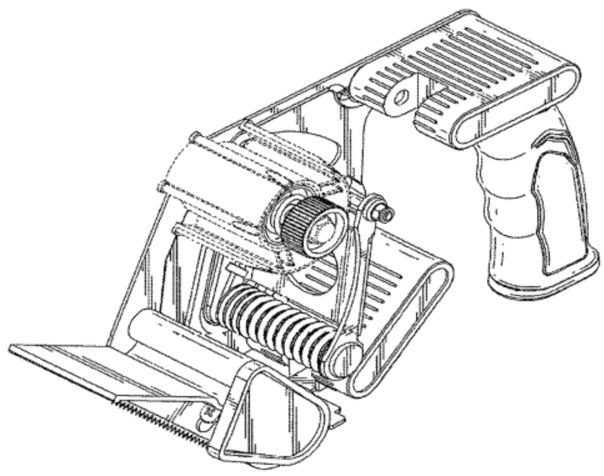


Figure 4: Patent Images for Tape Dispenser without Tape

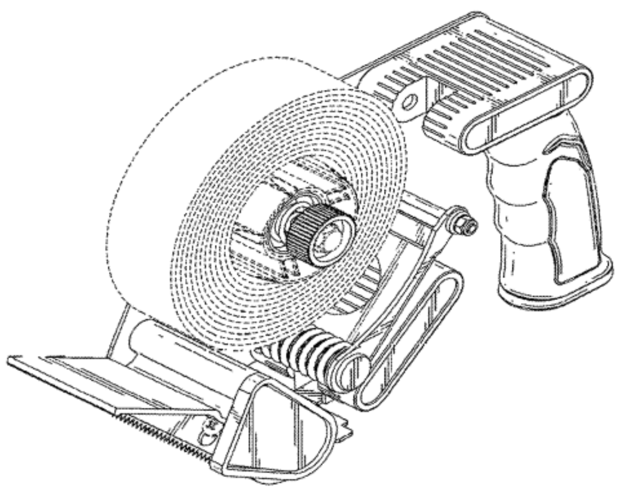


Figure 5: Patent Images for Tape Dispenser with Tape

2.2.2 X-Y MOVEMENT MECHANISM (US5341700A)

The patent is an X-Y movement mechanism that enables a movable member to be mounted directly on a fixed base so that the X-Y can move on a surface. There are X and Y directions, and the X direction has an angle relative to the Y direction, and they're both parallel to the upper and lower surfaces. There are two slots for sliding, non-rotating relative motion in the X and Y directions.

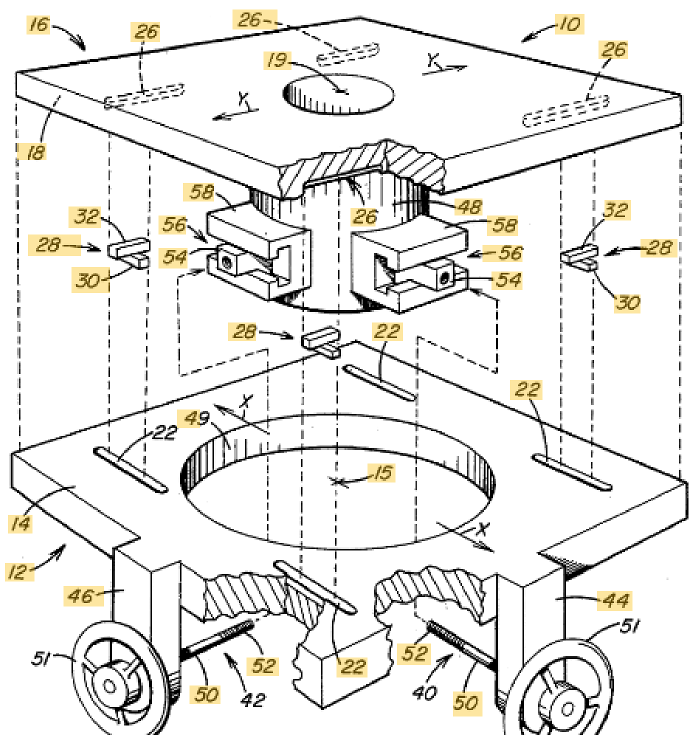


Figure 6: Patent Images for X-Y MOVEMENT MECHANISM

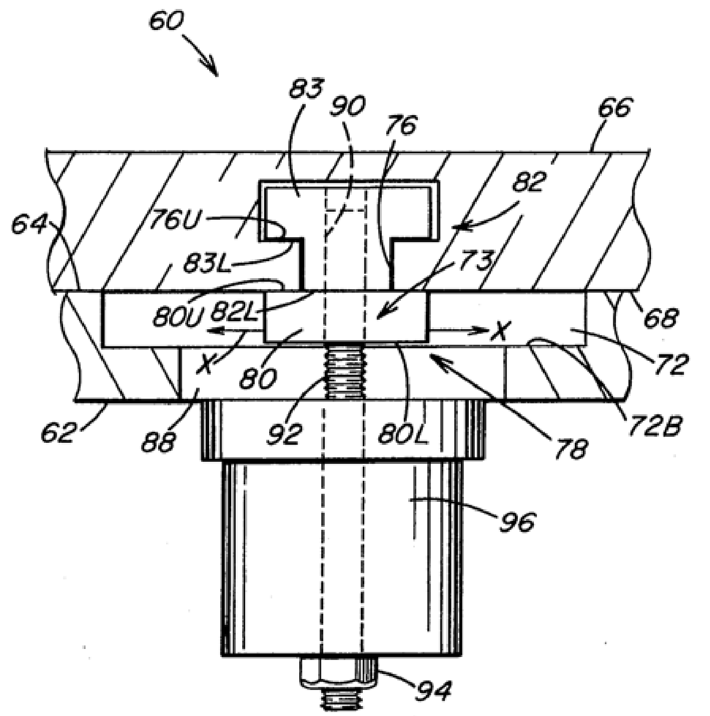


Figure 7: Patent Images for Section Extending in X Direction.

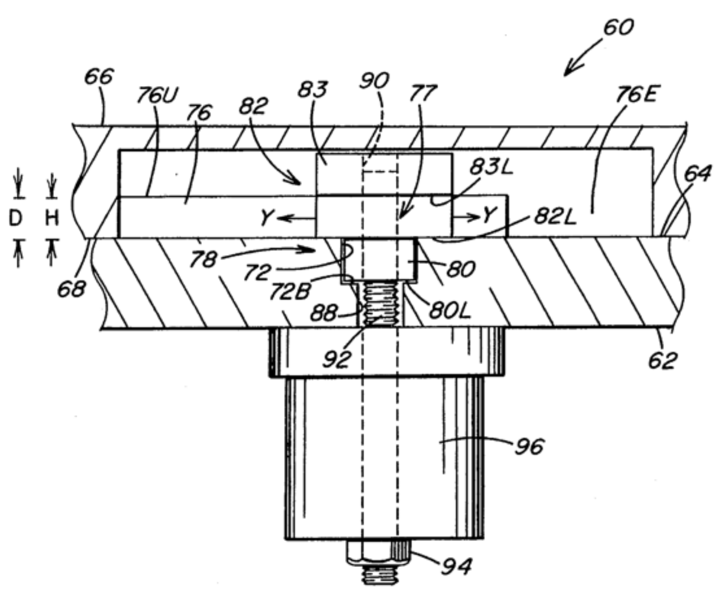


Figure 8: Patent Images for Section Extending in Y Direction.

2.3 Codes & Standards

2.3.1 Cutlery - Blade sharpness (ISO 8422-5:2004)

This International Standard is meant to regulate the type of blade used in cutlery for foodstuffs. The standard specifically says that any blade must have a pitch greater than 1mm, and must not be resharpened on a steel. In designing a T-shirt strip dispenser, different types of fabric strips will have to be cut, with some strips in a nondry state. Using a blade that's versatile to be used in any foodstuffs should prove useful here.

2.3.2 Plastics - Tensile properties (ASTM D638)

The American Society for Testing and Materials has outlined standards in measuring the tensile properties of plastics. Considering its low price, weight, and versatility, some type of plastic, 3D printed or otherwise, is highly likely to be used in our final dispenser.

2.4 User Needs

Our users are faculty & students of the Sam Fox School of Art and Design–specifically, Dr. Mary Ruppert-Stroescu, as well as any students and staff affiliated with the Fashion Design program. Designing a good strip dispenser has potential to not only help them here at WashU, but also serves as a starting point for anyone or anything interested in efficiently recycling fabric garments. This product allows us to solve both an environmental problem, and a practical problem.

2.4.1 Customer Interview

Interviewee: Dr. Mary Ruppert-Stroescu
Location: Bixby 14, Washington University in St. Louis, Danforth Campus
Date: September 9^{th}, 2022
Setting: Dr. Ruppert-Stroescu showed us sample fabrics, as well as fabric wheels our device would be working with. We saw and felt the different types of fabrics, discussed what our possible device could be, and learned what type of purposes and different materials our device should accommodate. The interview took place in her office, Bixby 14, as well as one of the fabric-working rooms within Bixby Hall, and it took ∼40 min.

Interview Notes:
What are the typical uses of the device?

- Dispense a roll of fabric and keep it in place as the user adjusts how long of a fabric strip they want.

What are the current likes and dislikes of the product?

- There's no current product as of right now. What Dr. Ruppert-Stroescu and students have been doing is manually dispensing each fabric roll by hand, and arranging or configuring the roll however they want to. This process can be tiresome, time-consuming, and physically-straining, but there's currently no other alternative to unspooling and stripping types of cotton.

2.4.2 Interpreted User Needs

In an ideal world, there would already be a tape dispenser gun out there that could easily hold a fabric, dispense it, and cut it, while the user could do whatever they please (pressing down, adding adhesive, et. cetera). In designing a device that serves this purpose, usability and efficiency are most important, with form being subservient to function.

Table 1: Interpreted Customer Needs

Need Number	Need	Importance
1	The roller can hold many types of wheeled fabrics, in varying condition (dry, wet, etc.)	5
2	The roller can easily reload	4
3	The roller can manually dispense fabric	5
4	The user has freedom to do what they want with a fabric while it it dispensed, including cutting it, or holding it still	3
5	The roller can be operated in whatever direction or ways the user desires	4
6	The roller is small and portable, or large and assemblable	2
7	The roller is aesthetically-pleasing	2

Aesthetic traits, as well as traits pertaining to storage and movement (excluding actual operation and efficiency in dispensing) are flexible, and don't need as much attention or care as traits that tie into executive function and operation. The roller must be approachable and usable by anyone, either in intuitivity for a novice operating individually, or easily-learnable from one student to another. Part of this utilizability means making a device that does one thing really well, but doesn't do everything by itself, as to allow for the user to do whatever else they want to do with the piece of fabric without this dispenser getting in the way. In essence, this device is an extension of the user, allowing them to do what they want (arranging used fabric strips) more efficiently than doing it all by hand.

2.5 Design Metrics

As of right now, the design metrics are, intentionally, vague and all-encompassing. There's a multitude of differences between the three existing devices we're basing our dispenser off of.

noticeable size and weight difference between the three

Table 2: Target Specifications

Metric Number	Associated Needs	Metric	Units	Acceptable	Ideal
1	4,5,6	Total weight	lbs	50	5
2	4,5,6	Total volume	in^3	≤ 10439	≥ 8
3	1,2	Diameter of inner fabric spool	in	< 2	≥ 1
4	1	Use lightweight, durable, cheap material such as plastics that can withstand moisture	binary	Pass	Pass
5	2,4	Include a gap within the dispenser for the user to remove & place fabric wheel	in^3	< 125	8
6	1,3,5	Make use of one or more parts of patent USD854616S1 inform dispenser apparatus design	binary	Pass	Pass
7	4	Blade pitch, as specified in ISO 8422-5:2004	mm	100	≥ 1

2.6 Project Management

The Gantt chart in Figure 9 gives an overview of the project schedule.

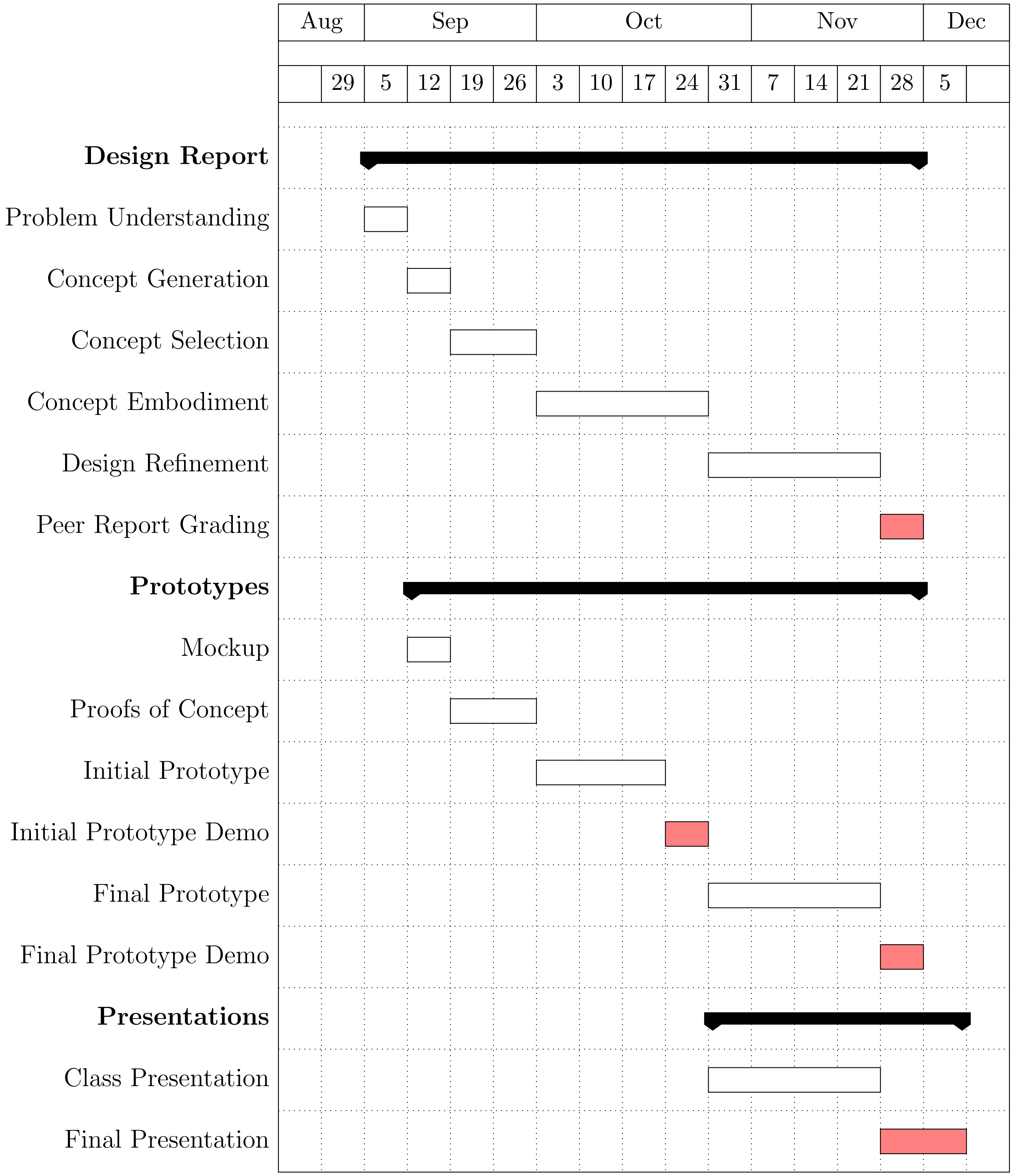


Figure 9: Gantt chart for design project

3 Concept Generation

3.1 Mockup Prototype

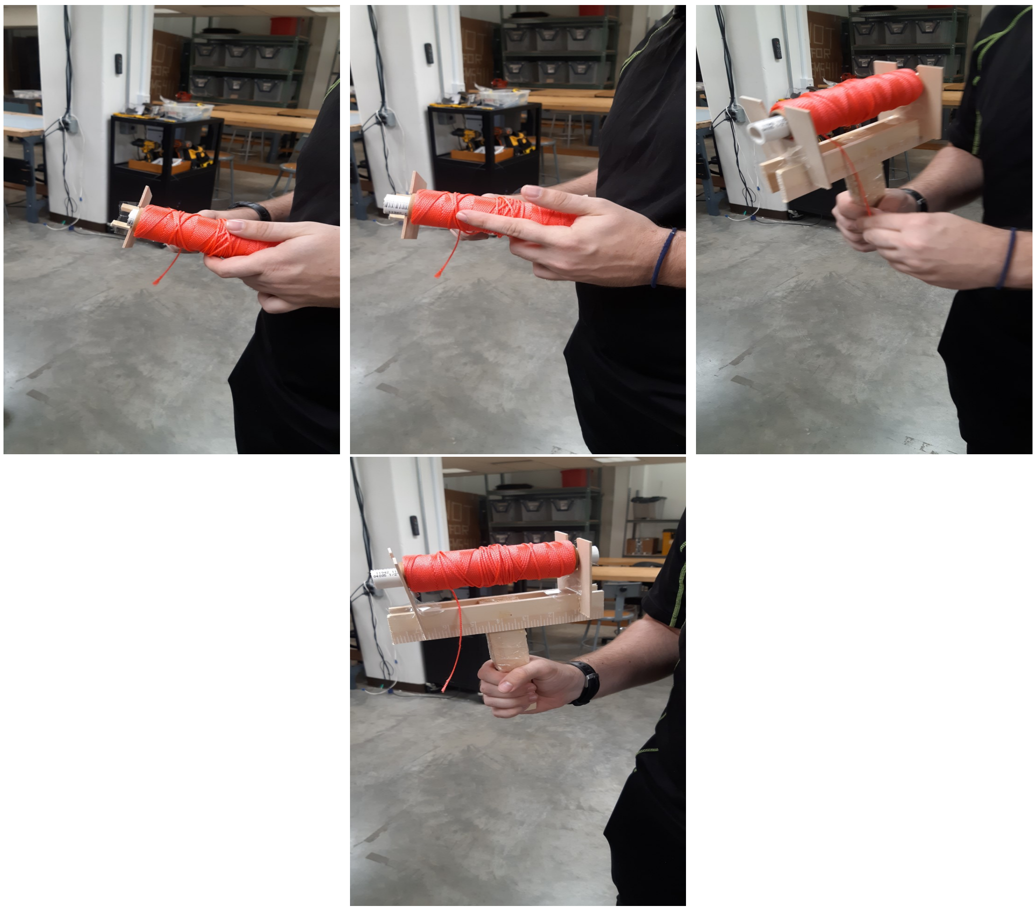


Figure 10: Pictures of Strip Dispenser Mockup

Our mockup gave us a visual of something that resembles the same sort of tape gun we've been thinking of for some time, or for the dispenser part of a wheeled chassis that would be similarly blocky as the 3D printer base. One significant issue we noticed upon assembly was the difficulty in attempting to reload and put in a new fabric wheel. The work-around we have in mind in future prototypes & models is to have a long, rotatable rod that could pivot, allowing for a fabric wheel to be removed and replaced as needed. Future designs would be based around using something similar to the mockup that can be just handheld or could also work on a wheeled chassis.

3.2 Functional Decomposition

The most important thing our T-Shirt Strip Dispenser must do is allow the user to have total control over the process of dispensing their strips of fabric. It follows, then, that the most important functions alongside that pertain to fitting fabrics and removing/loading a fabric wheel into the apparatus.

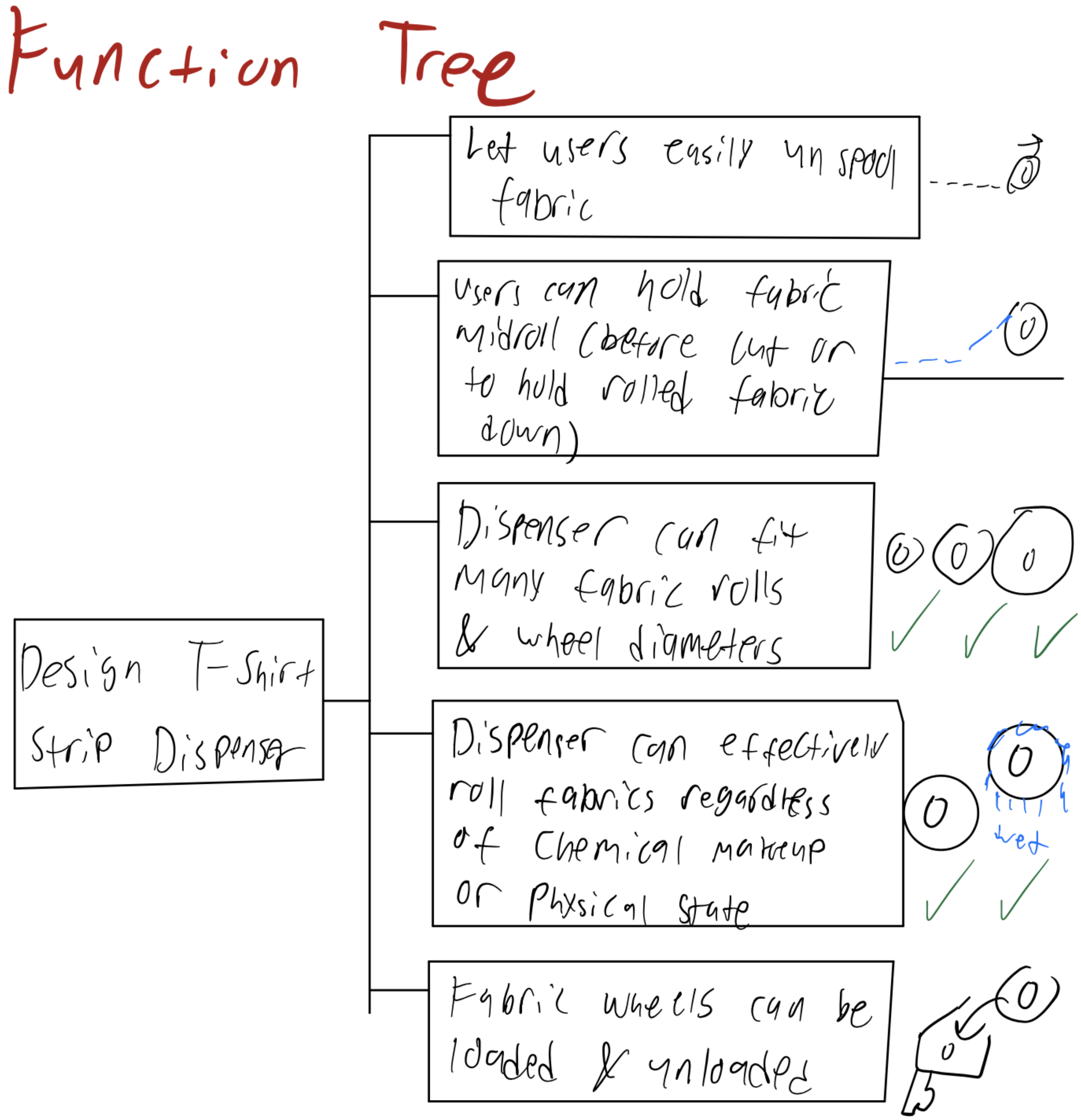


Figure 11: Function tree for T-Shirt Strip Dispenser, drawn on Notability

3.3 Morphological Chart

In visually designing strategies to implement our ideas into reality, we thought specifically of design techniques for our dispenser itself, as well as accessories or things we would have to tell the user how to make use of (such as including multiple spools of differing diameter, or of the swap-out point being spring-loaded).

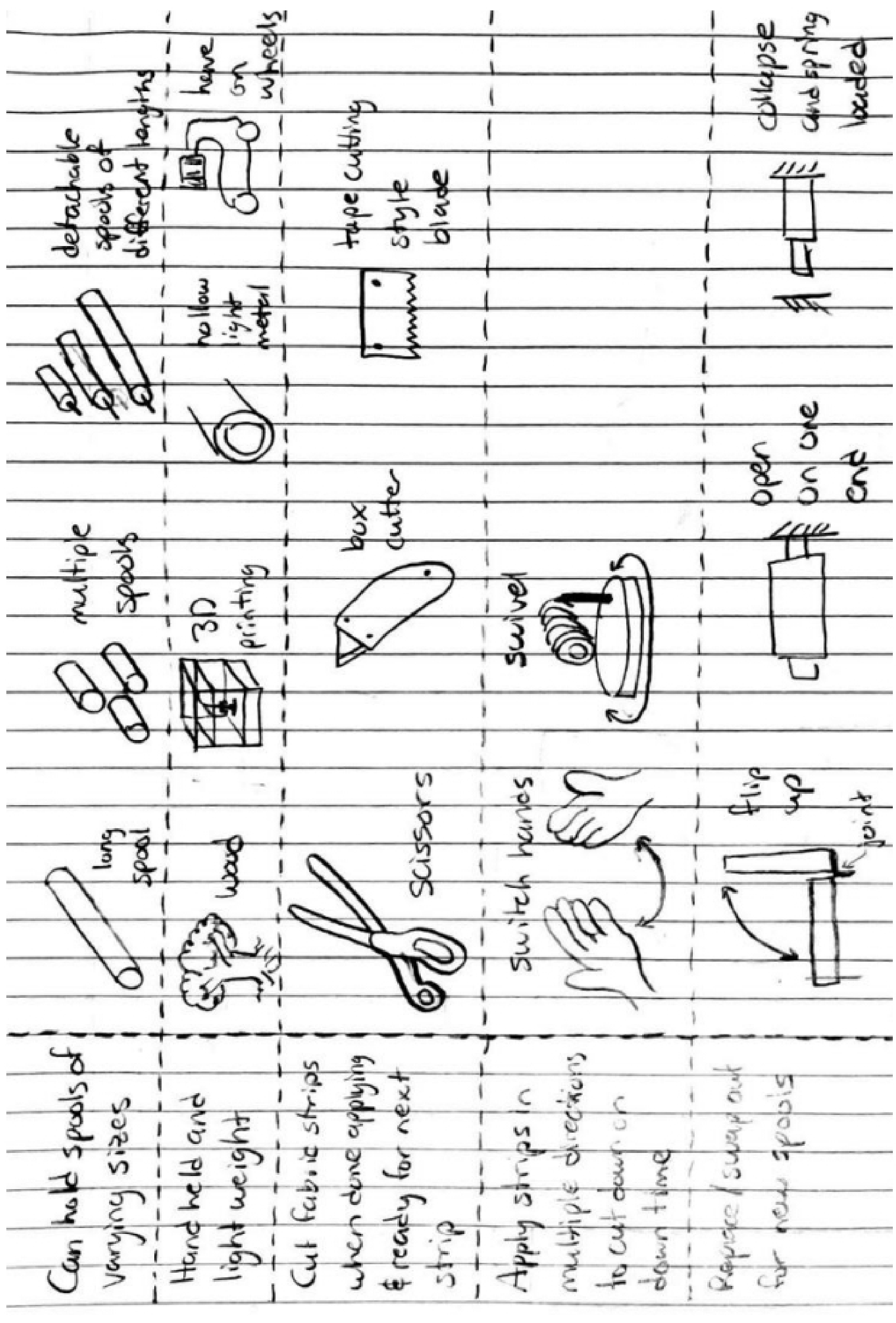


Figure 12: Morphological Chart for T-Shirt Strip Dispenser

3.4 Alternative Design Concepts

3.4.1 Concept #1: Dispenser Roller with Track

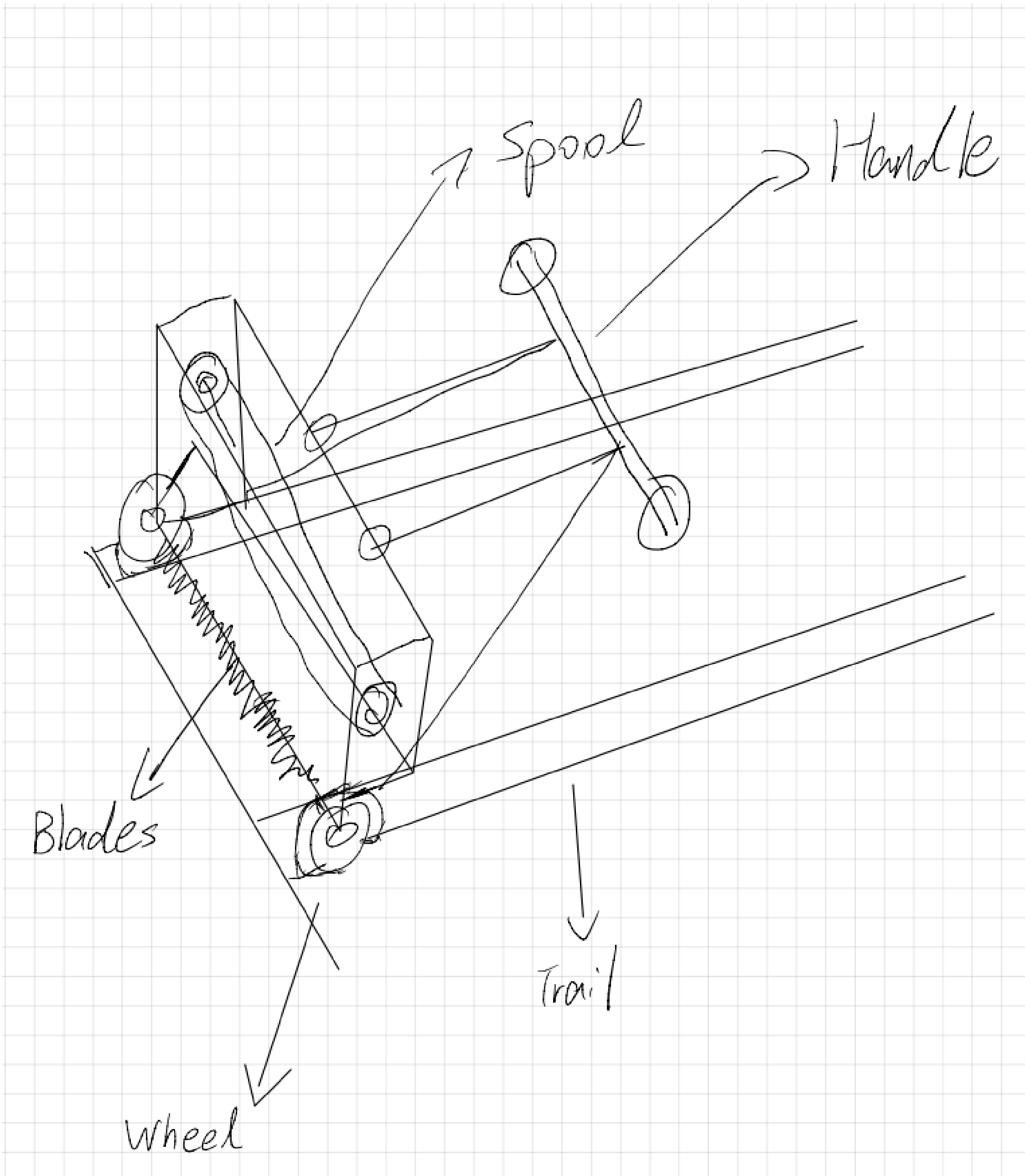


Figure 13: Sketches of Dispenser Roller with Track Concept

Description: This device contains two wheels attached to the side of the spool holder, and it can use with the track or without the track. If on the track, it will dispense straightforwardly. The spool can be put directly in the holder and taken out from the holder. On the holder, there is a blade or knife to cut the material after dispensing. The handle is attached to the holder and can rotate 180°, so it can turn around quickly when it approaches the end.

3.4.2 Concept #2: T-Shirt Strip Dispenser Machine Base

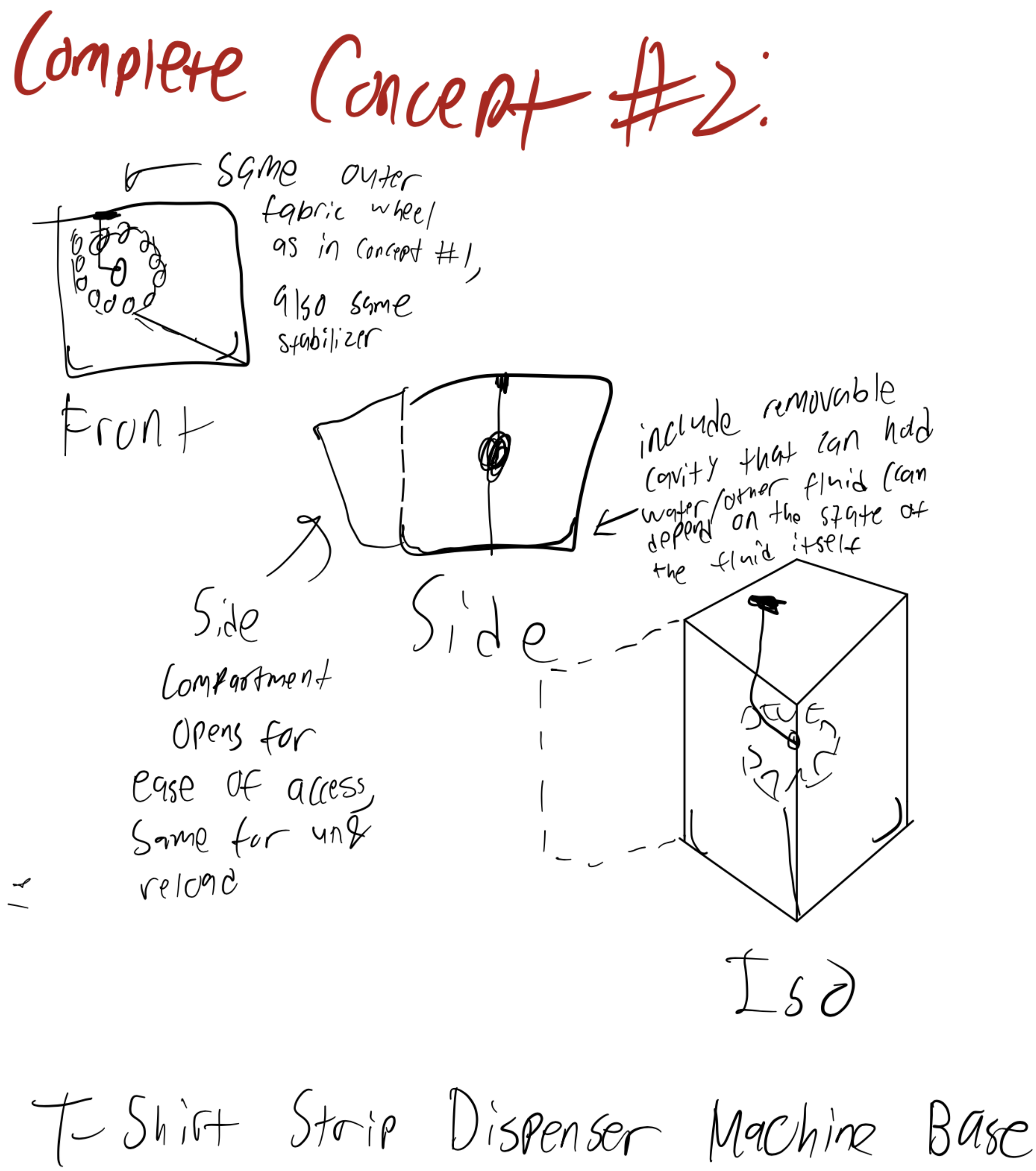


Figure 14: Sketch of T-Shirt Strip Dispenser Machine Base

<u>Description</u>: This device is based heavily on the cube-like aesthetic and functioning of a 3D printer. It would have a fabric wheel and dispenser at the top of the cube, and in the middle, with doors on the side opening for easy access and reloading. Below the wheel, there would be an optional track included for the fabric to follow upon dispensing, should the user want to make use of something like that. This would be sturdy and stable, to allow for fabric to be easily dispensed via the user spinning it out (there would likely be a handle on the top or inside of the cube, however something of this sort isn't shown in the picture above, as it is reliant on including other machinery).

3.4.3 Concept #3: Handheld Strip Dispenser

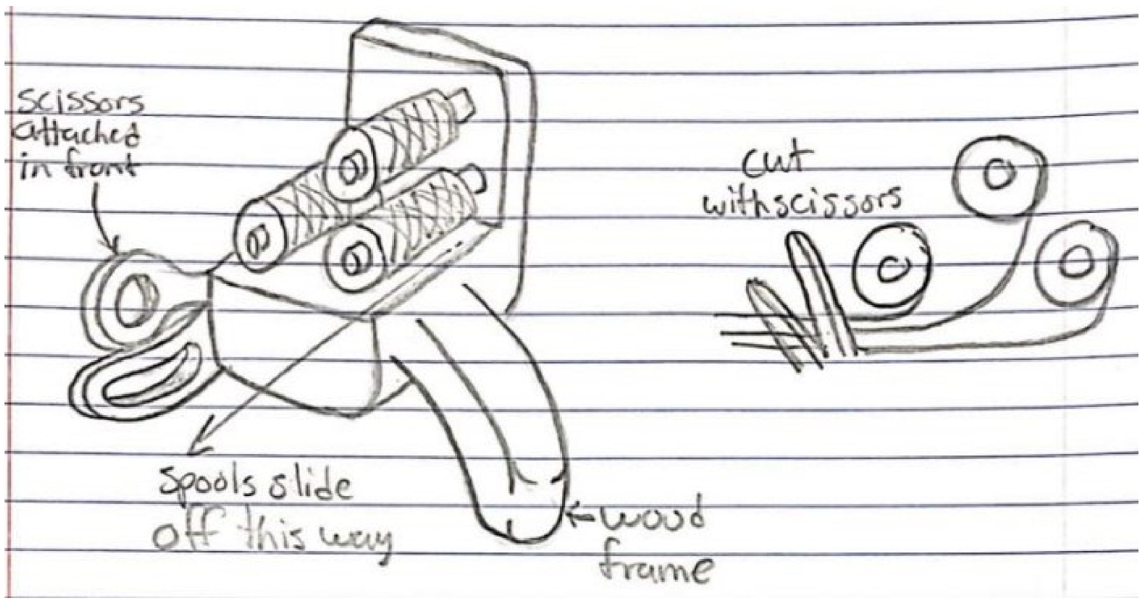


Figure 15: Sketch of Handheld Strip Dispenser

Description: This concept is designed to be be simple and without the use of any tracks. This design will also allow for more freedom of movement if strips need to be applied in the shape of a curve or on a curved surface. Some sort of blocker would needed to be added to the ends of the rods so that the spools do not slide of in the middle of using the apparatus.

3.4.4 Concept #4: T-shirt Strip Dispenser Pulley System

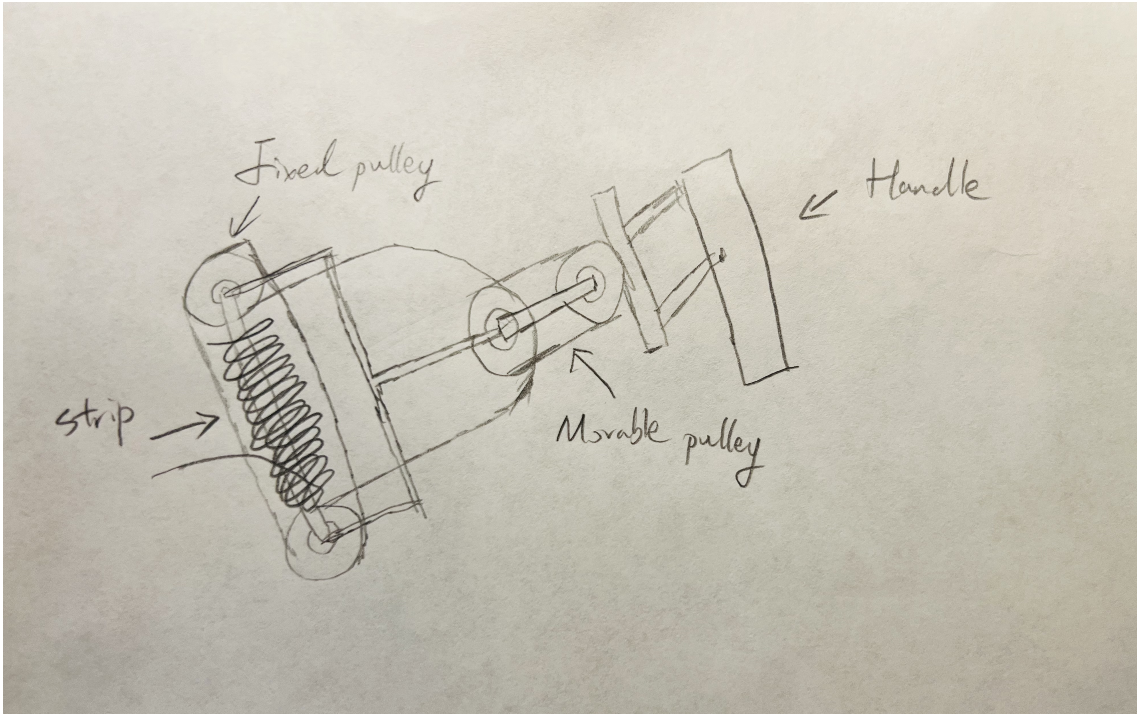


Figure 16: T-shirt Strip Dispenser Pulley System

Description: This system is attempted to minimize the force and pressure between the pulleys, wheels and surface. The strip is a highly subtle and sensitive material, that even a slight pull or stretch will result in plastic deformation. Therefore, it is important to reduce the friction between the parts of the dispenser. This pulley design combines fixed pulley and movable pulley, which can help holder to apply a smaller pressure on the handle to operate the dispenser as it used to be. It also makes the dispenser easier to turn around, since the fixed pulley can change the direction of the force.

4 Concept Selection

4.1 Selection Criteria

We have 5 criteria for our T-shirt Dispenser, which are easy to apply strips and reload spools, lightweight and intuitive, safety cut strips, user control of fabric application direction, and efficient application process. We compared each criteria with different criteria and rate them all. We agree that safety is strongly more important than any other criteria which weighted 50.24%, lightweight is second important which is 19.62%, easy to apply strips weighted 14.83%, 8.45% for control of fabric and 6.86% for efficiency.

	Easy to apply strips and reload spools	Lightweight and intuitive	Safely cut strips	User control of fabric application direction	Efficient application process	Row Total	Weight Value	Weight (%)
Easy to apply strips and reload spools	**1.00**	1.00	0.20	1.00	3.00	6.20	0.15	14.83
Lightweight and intuitive	1.00	**1.00**	0.20	3.00	3.00	8.20	0.20	19.62
Safely cut strips	5.00	5.00	**1.00**	5.00	5.00	21.00	0.50	50.24
User control of fabric application direction	1.00	0.33	0.20	**1.00**	1.00	3.53	0.08	8.45
Efficient application process	0.33	0.33	0.20	1.00	**1.00**	2.87	0.07	6.86
					Column Total:	**41.80**	**1.00**	**100.00**

Figure 17: Analytic Hierarchy Process (AHP) to determine scoring matrix weights

4.2 Concept Evaluation

We have 4 alternative design concepts, we compare each concept with other three and rate them based upon our analytic hierarchy process. Concept #3 has the highest score for our alternative design concepts, it is easy to apply strips and reload spools with lightweight and also has higher efficiency.

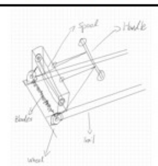
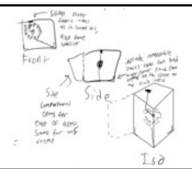
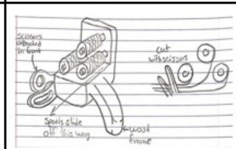
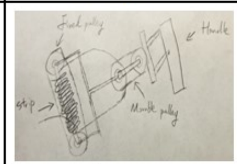
Alternative Design Concepts		**Concept #1**		**Concept #2**		**Concept #3**		**Concept #4**	
									
Selection Criterion	**Weight (%)**	**Rating**	**Weighted**	**Rating**	**Weighted**	**Rating**	**Weighted**	**Rating**	**Weighted**
Easy to apply strips and reload spools	14.83	5	0.74	3	0.44	4	0.59	3	0.44
Lightweight and intuitive	19.62	3	0.59	1	0.20	5	0.98	3	0.59
Safely cut strips	50.24	2	1.00	4	2.01	2	1.00	1	0.50
User control of fabric application direction	8.45	3	0.25	2	0.17	2	0.17	3	0.25
Efficient application process	6.86	5	0.34	2	0.14	5	0.34	4	0.27
	Total score	**2.931**		**2.957**		**3.091**		**2.064**	
	Rank	**3**		**2**		**1**		**4**	

Figure 18: Weighted Scoring Matrix (WSM) for choosing between alternative concepts

4.3 Evaluation Results

The winning prototype was Concept #3, as it provided the best balance of our criteria. It's meant to be gripped with one hand, and hold one or more spools, thus ranking highly in three of our five criteria. It didn't rank as highly in safety, however, as there is a blade of scissors at the end of the device, meaning the user must be mindful of the potential safety hazard. And this design feature also means there is a bit of a restriction on how the user can control strip dispensation. We believe for a device that involving wraps, adhesive and blades, safety is always the first priority. That is the reason safely cut strips weighed so heavily in the design criteria. For the alternative models, we think biggest problem is that they are complicated to design. For example, pulleys might reduce the friction between parts, but if we are going to create an actual prototype, there will be many difficulties because the sketch can't match the final product. Furthermore, since our goal for the dispenser is to make it as simple and light as possible, adding extra parts will increase its weight and makes it harder to control. Hence, if we want to make our device simple yet effective, we will need to come up with an accurate model design, and maximize the quality of each part. Our next steps are improving the prototype by calculating the needed force to reduce unnecessary design, and brainstorm new concepts may apply to it as we create the real model.

4.4 Engineering Models/Relationships

Model #1:

Our model is based on the premise of a chassis moving along the adhesive sheet on wheels as well as the handle holding the fabric moving along a track on the chassis. In both cases knowing the force required to overcome friction would be important to know and minimize to allow for the easiest use of the apparatus.

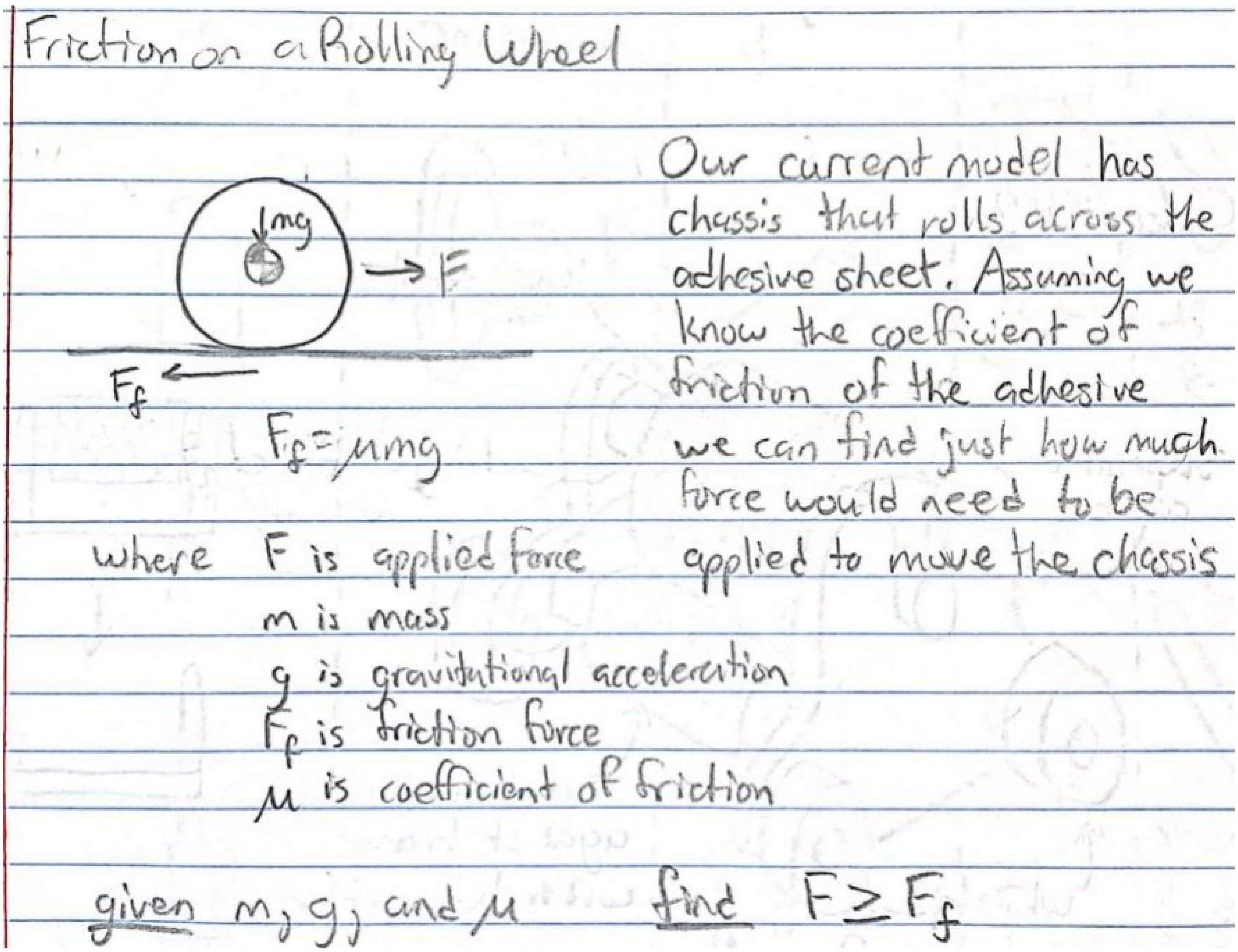
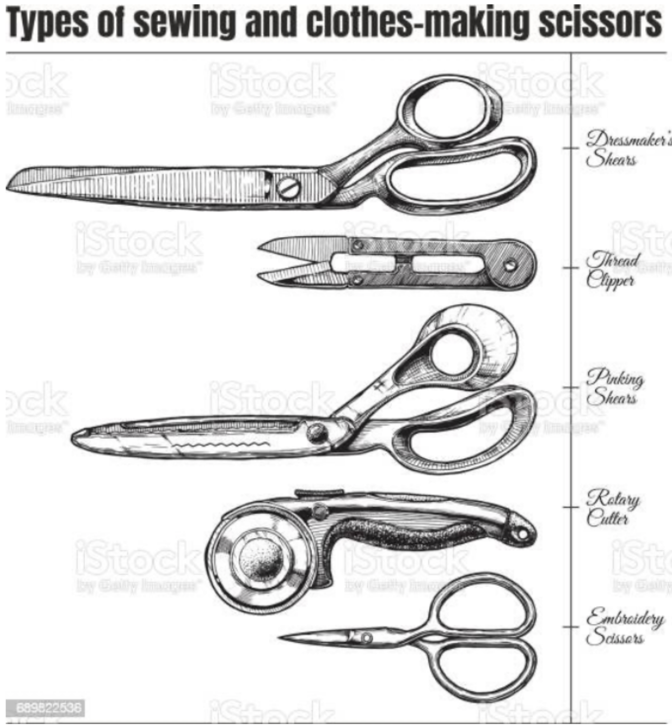
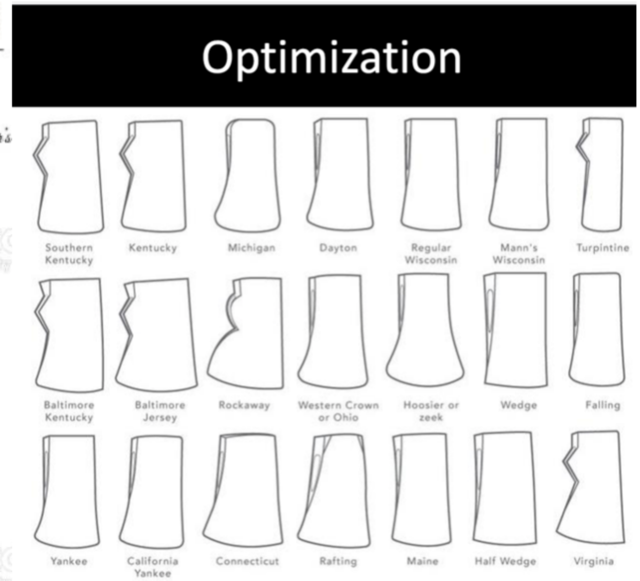


Figure 19: Engineering Model of Friction on a Rolling Wheel

Model #2:

An important aspect of the dispenser is making use of the most ideal blade for cutting fabrics. Rather than make something new, or work from the ground-up based off of target specifications and criteria, it's best to do both: draw from what's already in use and further re-purpose and optimize for what we are trying to make.





So this is loosely related to Optimization (specifically from Machine Elements Engineering Models lecture). My thought process is as follows: the blade of our strip dispenser must be able to cut through a variety of fabrics, that may also include fabrics of differing physical state (such as wet or dry). In the spirit of finding an optimal blade for fabric cutting (similar to the process outlined in finding a blade for wood splitting), it's likely best to use the type of blade and/or design of sewing scissors, as these scissors work specifically for fabrics and using an unoptimal blade will likely increase dullness (source: https://www.vampiretools.com/will-cutting-the-wrong-thing-blunt-my-scissors/)

Important Parameters, variables include:

- blade angle, θ
- serrations across blade, can be simplified as semicircles that are spaced out X cm or mm apart from each other, along length of blade
- It's also ~~best~~ best to use steel/aluminum or another metal, as these materials have high yield strength, in part thanks to carbon
  - MatSci!

Figure 20: Engineering Model of Different Scissors Specific to Cutting Clothes

Model #3:

Depending on the design of and the frequency with which the apparatus will be used, it is logical that the handle will undergo fatigue. Find what force would cause deflection and possible breaking of the hand would be extremely important to know to increase the life of the handle. This information will also help in deciding what material should be used to make the handle.

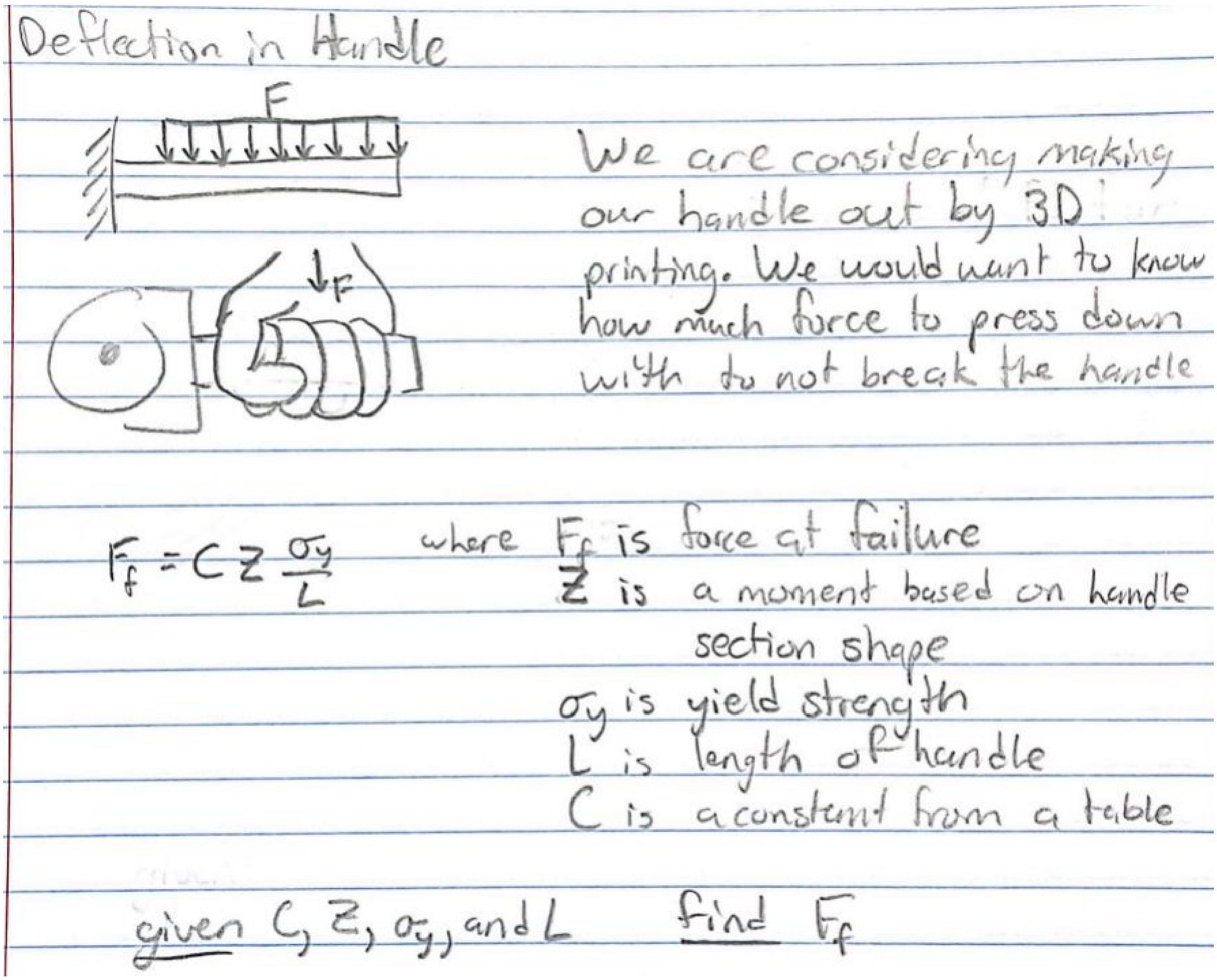


Figure 21: Engineering Model of Possible Deflection Experience Under the Force Caused by Hand

5 Concept Embodiment

5.1 Initial Embodiment

Below are drawings of the first prototype, alongside the prototype performance goals.

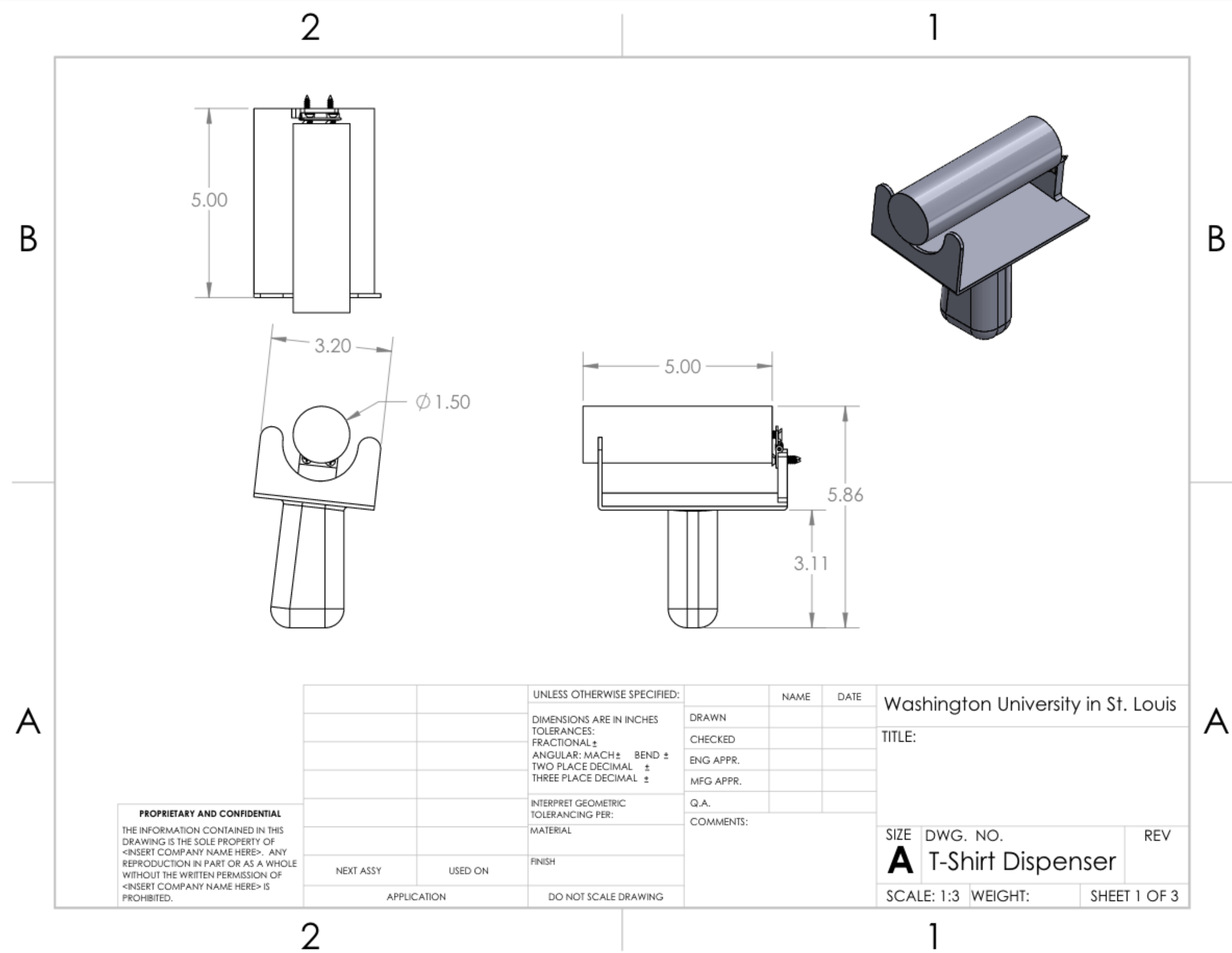


Figure 22: Assembled projected views with overall dimensions

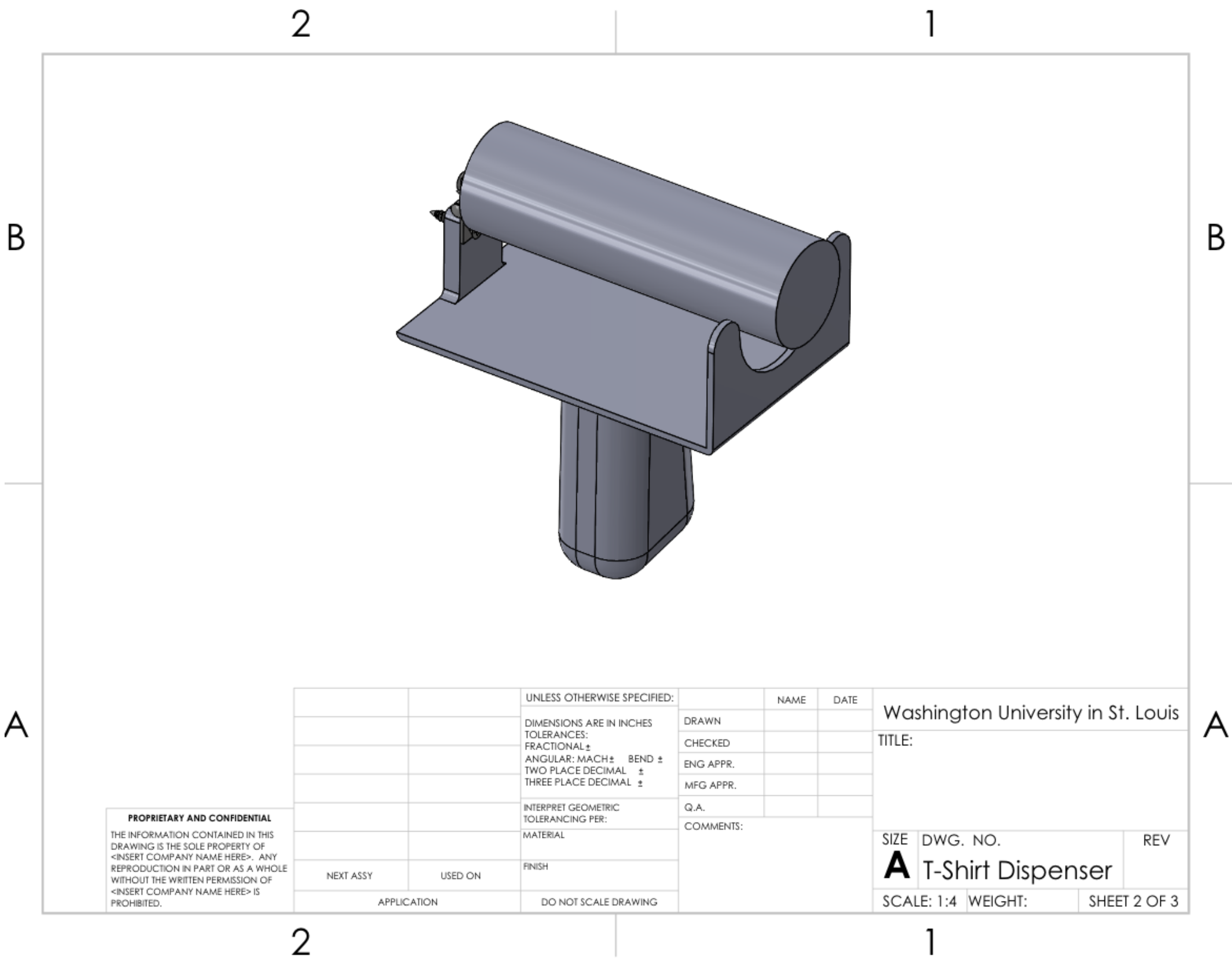


Figure 23: Assembled isometric view with bill of materials (BOM)

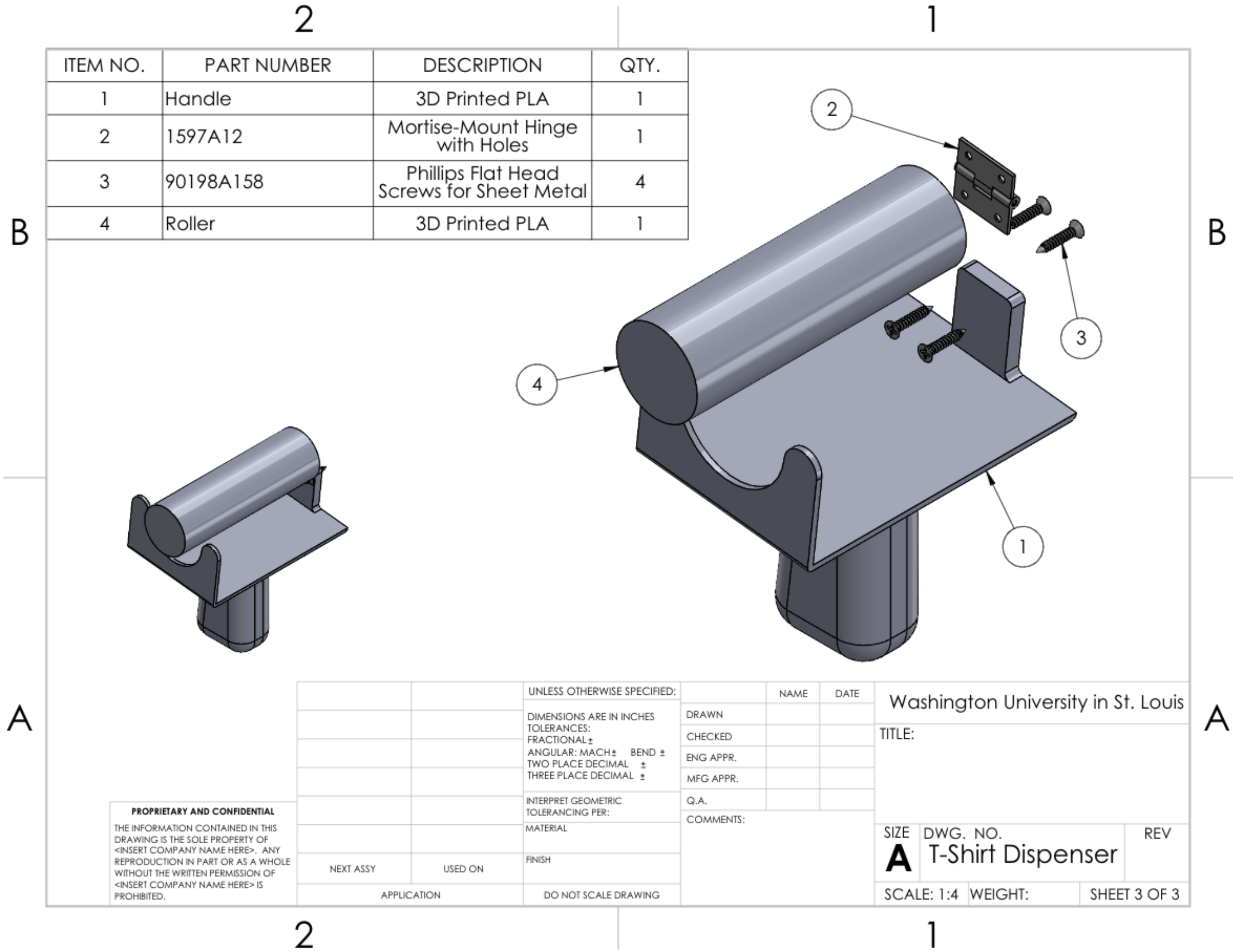


Figure 24: Exploded view with callout to BOM

D, G, J, O, U	T-shirt Strip Dispenser	The device can be used to lay-down and cut 5 two-foot-long strips of fabric in ≤ 1 minute.	After the Goal 1 test, ≥ 4 of the strips are well-adhered to the backing and show negligible warp/stretch.	The roll of fabric can be replaced in ≤ 30 seconds.

Figure 25: Prototype Performance Goals

5.2 Proofs-of-Concept

Our initial mockup gave us the chance to make a very general dispenser and track for it, thus serving as a model for how to make a prototype that focused exclusively on dispensing. For instance, in making the mockup we learned we could design the dispenser to have a spool that would rotate in order to make the unloading and reloading process easier.

5.3 Design Changes

The biggest changes from the Concept Selection stage up to now have been for simplicity: we have yet to include any sort of scissor slot. We decided it's best to keep scissors out of the final dispenser, for a few reasons: we don't know the best fabric scissors, the dimensions of the blades and handles, it may be preferable for the user to cut the strips separately (as shown in our class presentation video), and we have to design and position the scissors such that they would only cut the strip when the user desires, and would stay open otherwise. Additionally, we only have one spool, as opposed to three at varying diameters. In the event we choose to keep the spool and dispensing apparatus the same for our final project, we hope to talk with Dr. Ruppert-Stroescu again to get a better understanding of optimal diameters of fabric wheels the dispenser needs to accommoadate. 8

6 Design Refinement

6.1 Model-Based Design Decisions

Model #1

In our mockup, we planned on designing a chassis system to accompany our dispenser, and part of this system makes use of wheels moving on a track. In revising this idea in time for our final prototype, we decided to calculate the force of friction on a rolling wheel. Assuming the mass the wheels move consists of the dispenser and a roll of fabric, and that the surface is steel (with its consequent friction coefficient of 0.19 [2]), the user must apply a force greater than the calculated friction force, which was 0.2442 Newtons, or about 0.05 pounds-force.

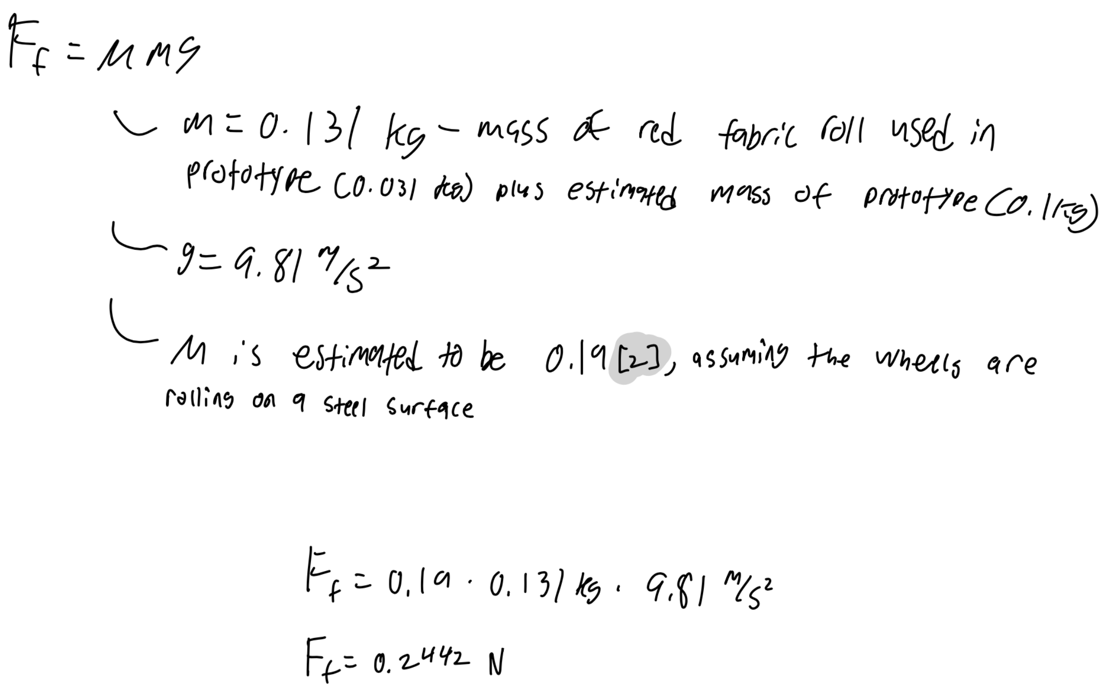


Figure 26: Model #1 Calculations

Model #2

The previous Model #2, detailing blade pitch and other details in cutting fabrics, proved to be inapplicable, as scissors are expected to be provided by and operated independently by the user of the dispenser. A new Model was created, with this one focusing on a fabric guide rod we hope to include in our final dispenser.

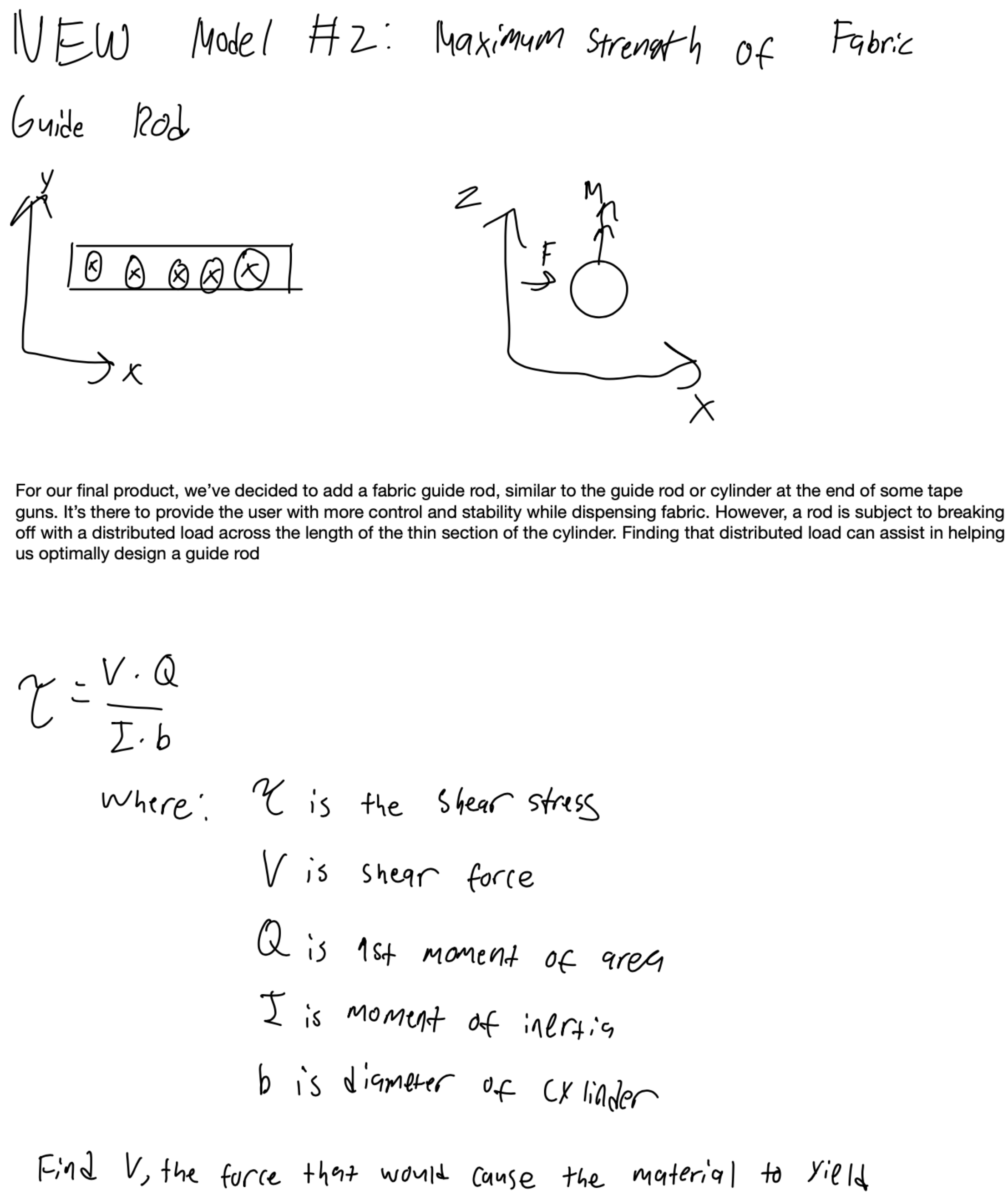


Figure 27: New, Updated Model #2

With the yield strength of PLA plastic available online[3], and assuming values for the hypothetical diameter, mass, and length of a smaller guide rod, values for the moment of inertia and first moment of area can be found, with the only uncertainty remaining the shear force that would cause PLA plastic to yield. The shear force needed to bring the plastic into yielding is approximately 7 million Newtons, a large value that gives added confidence in the decision to add a guide rod.

- Assuming $\sigma_y = \tau$ via the maximum principle stress theory
  - yield strength of PLA Plastic = 26.082 MPa [3]
- Assume diameter, b, of the rod is 0.0254m
- Assume rod has a mass of 0.05kg
- Assume rod has a length of 0.13462m
- I is $\frac{1}{4}MR^2 + \frac{1}{12}ML^2$
  - $I = 7.15 \times 10^{-5}$
- Q is centroid · Area, or $\left(\frac{0.0254m}{2}\right) \cdot \pi \left(\frac{0.0254m}{2}\right)^2$
  - $Q = 6.43 \times 10^{-6}$

$$26082000 \ Pa = \frac{V \cdot 6.43 \times 10^{-6}}{(7.15 \times 10^{-5}) \cdot (0.0254)}$$

$$\boxed{V = 7984 \times 10^3 \ N}$$

Figure 28: New, Updated Model #2

Model #3

Using the same value for PLA yield strength as before, finding a constant C from another textbook, and using values for length, base, and height from the prototype, the value for the force needed to break the handla apart was calculated to be 6,060 Newtons. This value proves a similar point to the end result shown in the new Model #2 above: PLA plastic is a very durable material that should be sufficient for the amount of Newtons most people would exert in dispensing the fabric.

$$F_f = C \cdot Z \cdot \frac{\sigma_y}{L}$$

- σ_y is yield strength of PLA plastic: 26.082 MPa
- L, handle length, is 3.11 inches
- Z, moment, is derived from assuming the handle is a rectangle,

$$\Rightarrow Z = \frac{bh^2}{6} \qquad h = 1.61\,in \quad b = 1.3\,in$$

$$= \frac{(1.3\,in)(1.61\,in)^2}{6} = 0.56\,in^3$$

C = 2 from a table in a pdf appendix given to Joseph in MEMS 4101 Manufacturing processes

$$\Rightarrow F_f = (2)(0.56\,in^3)\left(\frac{0.0254\,m}{1\,in}\right)^3\left(\frac{1}{3.11\,in}\right)\left(\frac{1\,in}{0.0254\,m}\right)(26.082\,MPa)\left(\frac{10^6\,N/m^2}{1\,MPa}\right)$$

$$Pa = N/m^2 \qquad \Rightarrow F_f = 6060\,N$$

Figure 29: Model #3 Calculations

6.2 Design for Safety

6.2.1 Risk #1: Screw Puncture

Description: In the first prototype, the exposed ends of the screw are sticking out of the dispenser. While these ends are away from the user and away from their hand or the fabric, there is still a risk of injury, namely if other people not operating the dispenser are in close contact with it or if it were to fall on someone or their toes.
Severity: Marginal
Probability: Seldom
Mitigating Steps: Design panel holding screws to be thicker than in prototype, or we could just put the screws in such that the tips are facing the opposite direction.

6.2.2 Risk #2: Plastic Fragility

Description: The handle and base of the dispenser are firm, but thin in some areas, and made of the same PLA plastic material. If someone accidentally drops the dispenser on the floor, depending on the point of impact, it is possible there will be deformation or a significant crack in the object.
Severity: Catastrophic
Probability: Seldom

Mitigating Steps: To prevent someone from damaging this device by accident, we need to make sure that no one is moving around it that may have contact with the device while it is working, and also hold it carefully so it won't fall.

6.2.3 Risk #3: Spool Slip

Description: In our first prototype, we didn't add a cover for the fabric wheel once on the roller, so it can easily come out while dispensing. This has potential to complicate the dispensing process or surprise the user, which could result in a fall, for instance.
Severity: Marginal
Probability: Likely
Mitigating Steps: Design a cover or increase the diameter of the roll, so fabric wheel can attach or fasten on the roll and also can easily dispense.

6.2.4 Risk #4: Cutting Oneself or Others

Description: Scissors or a blade of the user's choice are operated separately from the dispenser, but necessary in cutting the strip from the dispenser and onto the desired surface. Depending on scissor sharpness, strength, and ease or struggle in cutting, there is a chance the user might bring their fingers in close contact with scissor blades.
Severity: Marginal
Probability: Seldom
Mitigating Steps: Improve dispensing process by adding an additional piece to the base to assist with strip distribution (making it easier for the user to measure what they want and cut the strip themselves)

6.2.5 Risk #5: Risk of Screw Coming Loose/Apart

Description: Whatever is kept in place with one or more screws must be tightened professionally and designed to minimize the potential of a screw coming apart due to age or heavy use.
Severity: Marginal
Probability: Unlikely
Mitigating Steps: Continue making use of washers to minimize stress and miniature deformation on PLA plastic, continue designing to minimize exposed screw ends.

	Probability that something will go wrong				
Category	**Frequent** Likely to occur immediately or in a short period of time; expected to occur frequently	**Likely** Quite likely to occur in time	**Occasional** May occur in time	**Seldom** Not likely to occur but possible	**Unlikely** Unlikely to occur
Catastrophic					Plastic Fragility
Critical					
Marginal		Spool Slip	Risk of screw coming loose/apart	Screw Puncture Cutting Oneself or Others	
Negligible hazard presents a minimal threat to safety, health, and well-being of participants; trivial					

Figure 30: Heat Map

As indicated by the heat image map, the most critical risk stems from the fragility of plastic, as it could break, and depending on the impact and how the roller is affected, it could be catastrophic. From there, the next critical risk is the fabric spool slipping off of the roller, which could occur with frequent and heavy use, but can easily be prevented by user attentiveness (assuming the user is able to recognize and react to a loose wheel). Finally, these next three risks are all marginal, and either occasional or seldom likely to occur: screw loosening or breaking, and screw puncture/cutting oneself or others (in that order). A screw does have potential to come apart or become looser in time, but this is heavily dependent on use and user strength. By modeling our final prototype more closely to that of a tape gun, and including an extra piece of plastic to assist with distributing fabric, it will make dispensing fabric easier. Similarly, by thickening the plate screws get screwed into and altering our design, the chances of a screw being exposed, let alone puncturing someone, will be drastically reduced.

6.3 Design for Manufacturing

With our initial prototype in mind, there are currently only three parts: the handle+base combination, the roller, and a miniature hinge–these are also our TNCs. There's also only four threaded fasteners: Phillip's Flat Head Screws (0.5" long screws). The handle+base combination combines the handle, the way the user will grab and operate the strip dispenser to begin with, with the horizontal base of the dispenser that provides structural support and a point of connection for the roller. The roller is designed to hold the wheel of fabric as it's being dispensed, and the miniature hinge serves as a point of connection (with threaded fasteners) between the handle+base and the roller. Since this prototype is close to the minimum number of TNCs, one thing to decouple could be the handle+base into just a handle and base, attachable via threaded fasteners or by snapping panels into place.

6.4 Design for Usability

A strong visual impairment, such as blindness or nearsightedness, can affect usability of the device, because it's a lot harder to appropriately lay strips out if you can't see what you're doing, or the strips themselves. This may bring another design challenge, but one way to improve usability for a visual impairment could be designing a tape measure right by the mouth of the dispenser, which can let someone with trouble seeing measure out how much of the fabric they would want to dispense before dispensing that much fabric. Braille can also be designed into the tape measure, allowing someone who is blind to feel how much they've measured out.

A hearing impairment should not significantly impact usability of the device. This is because the act of laying out strips, adhering them onto paper, and then cutting them is largely visual and physical, requiring or making very little use of hearing. It is possible that an audible snap noise (like discussed above) could confirm that a roll is loaded in place, but visual inspection can also confirm the same thing.

A physical impairment does impact usability of the device, as holding it while measuring is necessary in dispensing the strips. The tape dispenser idea from above might be useful, but instead of having a dispenser to the side, it can be positioned on top and connected to the fabric, allowing for someone to hold the dispenser at the edge of a table (in an attempt to keep the dispenser flat instead of raised) while measuring with the tape measure. Finally, a blade that can move up and down at the mouth of the dispenser can cut the amount of the strip one measures out, and eliminate the use of something like scissors, which could be physically demanding for some.

A control impairment can impact use of the device, such as having to hold the strip down, move the dispenser back, and later cut it. Aside from the tape measure idea discussed above, another potential modification is to make use of a weight in the roller (like those used in spoons for parkinsons patients), that way it can stay static even if the user's hands aren't.

7 Final Prototype

7.1 Overview

Our final dispenser is much easier to work with than the initial prototype, thanks in part to the improvements made to the handle, and also by adding the guide roll in front of the bolted-on roller. It's also been improved for safety by shaving off the exposed screw ends, and has been made more secure by using a wire with a high stiffness as a locking mechanism. However, the same difficulty in laying out five strips within a minute and thirty seconds was present in both the initial, and final, prototypes. We believe that proper spacing between fabric lines and the adhesive and variability in how a user dispenses can improve the amount of time it takes to dispense fabric strips, hopefully meeting the initial performance goal.

7.2 Documentation

Figure 31: Isometric view of Dispenser STL File

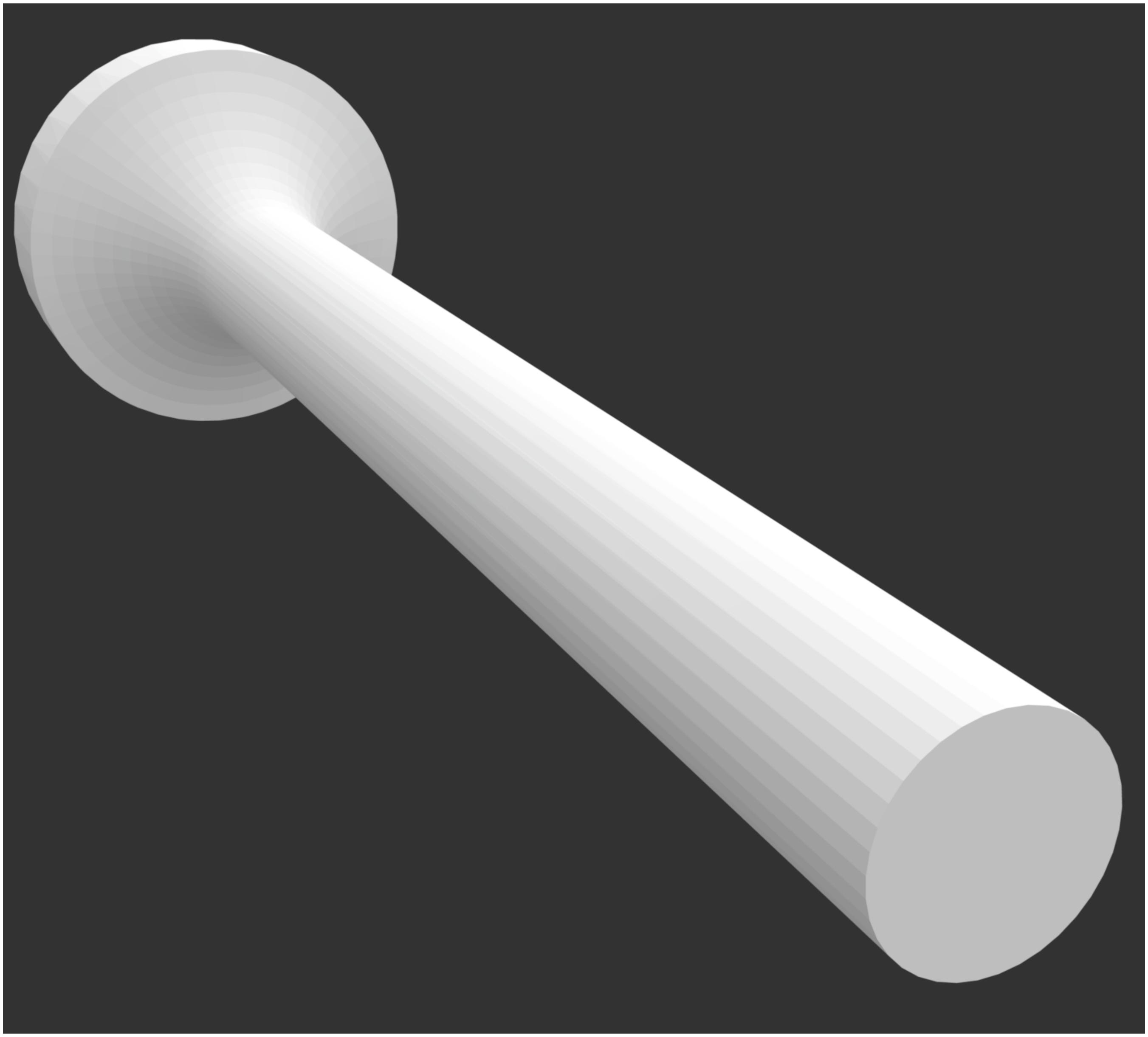


Figure 32: Isometric view of Roller STL File

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[1] *Scotch® Low Noise Tape Dispenser H150*. URL: https://www.3m.com/3M/en_US/p/d/b40069553/.

[2] *Friction Coefficient On A Stainless Steel Surface*. URL: https://www.researchgate.net/figure/Friction-coefficients-on-a-stainless-steel-surface_tbl2_296483729.

[3] *Yield Strength for PLA Plastic*. URL: https://aip.scitation.org/doi/10.1063/1.5085981#:~:text=Its%5C%20optimum%5C%20mechanical%5C%20property%5C%20is,26.082%5C%20MPa%5C%20for%5C%20yield%5C%20strength..