Department of Mechanical and Mechatronics Engineering

ME 101: Adjustable Standing Table

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Summary

With the impact of the COVID-19 pandemic becoming a major factor for the present working environment, there have been many workplace adaptations made to ensure the safety of employees worldwide. The most prevalent of these adaptations being the work from home order, where employees are required to perform their duties from a personal location. With the increase in home office use comes an increase in health problems related to long periods of sitting without proper back and posture support. This standing desk design resolves such health problems by offering a variety of desk heights allowing the user to stand while utilizing the desk. The need statement for this design is, "There exists a need to elevate desks to a desirable standing height while meeting the safety requirement and regulations of a desk."

After sketching an initial prototype and creating a preliminary SolidWorks design, it became inherently clear that important changes needed to be made. These changes included developing a new vertical motion mechanism and having a centered leg design while finding a way to prevent the tabletop from rotating with the assembly. With the research and testing of different designs, it became apparent that a threaded worm gear was best suited to achieve the vertical motion of the desk. This is accomplished by implementing a screw jack mechanism with reduced gear ratios. This vertical motion apparatus is contained within a box and telescoping tubes are attached to a bearing to allow the rotational movement of the lead screw but prevent any transfer of rotational energy to the tabletop.

With the design and mechanics of the desk finalized, a series of tests were performed based on the engineering specification made. These specifications were created to ensure the desk design would not interfere with normal use and could safely hold the weight of itself and heavy objects while ascending and descending numerous times. Measuring the difference between the fully contracted and fully extended desk height allowed for the assurance that the desk would meet the ergonomic requirement of being at a standing level for the average user. By conducting an FEA, the maximum weight capable of being safely supported by the desk was determined and design elements were adjusted for it to be in an acceptable range. Also, an analysis of parts allowed for a cost breakdown to ensure the standing desk design was affordable and within budget.

After prototyping, testing, and finalizing, it is concluded that this standing desk design meets every requirement in the engineering specification while solving the need statement created. However, it is recommended that two desk legs are utilized on either side due to the need for more leg space by the user. Using one lead screw to lift the desk requires a large pole placed in the center of the desk that takes away from the user's space and complicates the verification of stability.

Introduction

The objective of this design project is to identify and improve an existing mechanical engineering system. To achieve this, the group decided to improve upon standing desk designs to provide the perfect solution for the health problems experienced due to sitting for long periods of time. At the end of August 2020, 40% of workplaces across Ontario reported that 90% or more of their workforce was working from home (Lamb, 2021). With the percent increase in people working from home, came a spike in online complaints about back and posture health issues. Some of these complaints include back stiffness, soreness and spasms. While many workplaces are seeing an increase in productivity, some have had to take time off due to health issues. By using the group’s design, workplace productivity will increase because of the solution the standing desk provides for many health issues. The unique elements of this design allow for efficient ascending and descending and provide an easy user interface with the placement of the handle. While being cost effective and offering an easy solution for people facing recent health issues, this design is a perfect solution to a major issue revealed because of the pandemic.

Needs Analysis

During COVID-19 the amount of time students, employers, and employees spend sitting down and staring at a screen has increased significantly. These extended periods of sitting can cause a major problem in terms of health, such as back or spine injury and even productivity. Over time, the consistent routine of sitting for long periods can lead to other long-term health issues as well. For this, the following need statement was developed:

"There exists a need to elevate desks to a desirable standing height while meeting the safety requirement and regulations of a desk."

The project objective is to try and reduce the amount of sitting by providing an option to stand through the elevation of a desk, leading to a more productive and healthier lifestyle.

Table 1 Engineering Specifications

No.	Characteristic	Relation	Value	Units	Verification Method	Comments
1	Must elevate desk to desired standing height (Functional Requirement)	>= and <=	30 and 46	inches	analysis	Measure the minimum and maximum additional elevation that the desk gains and verify that it is within range.
2	Must be portable and able to be moved quickly with the ability to be locked in place (Non-Functional Requirement)	N/A	N/A	N/A	analysis	Analyze the portability and ease of moving (analyzing resistance and smoothness of moving).

3	Must withstand desk weight and weight of objects placed on desk (Functional Requirement)	>= and <=	0 and 150	kg	analysis	Perform an FEA simulation on the applicable components of the table.
4	Must not tip over and keep desk at a level surface (Constraint Requirement)	<	5	degrees	analysis	Measure the desk surface with a level to verify that its surface is not tilted more than 5 degrees.
5	Must not make noise during elevation (Non-functional Requirement)	N/A	N/A	N/A	examination	Must not make any noise during elevation or adjusting (which may otherwise be presented in other products like ours)
6	Must be within cost range (Constraint Requirement)	>= and <=	0 and 1000	CAD ($)	analysis	Add the estimated cost of manufacturing costs, materials, and labour
7	Must be easy and intuitive to use (Non-functional Requirement)	<	5	minutes	test	Must be intuitive and easy to user and user should know how to use it within 5 minutes. Sample of 20 people and at least 80% must be able to use within 5 minutes.

8	Does not interfere with regular table use (Non-functional Requirement)	N/A	N/A	N/A	demonstration	Must be used identically to a regular non-adjustable table and must not interfere with regular use of table.

From the following need statement, engineering specifications in Table 1 were derived.

Conceptual Design

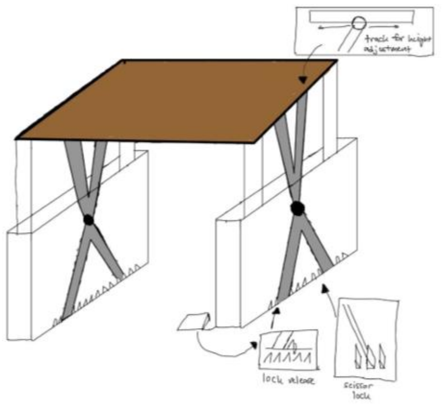

Figure 1: Concept Design Number 1 containing a scissor lock mechanism, mechanical linkage. and unique table frame design.

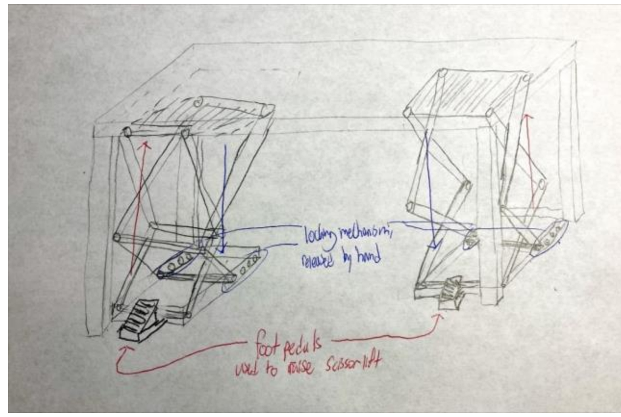

Figure 2: Concept Design Number 2 containing a scissor lift, mechanical locking mechanism, and under-table structure design

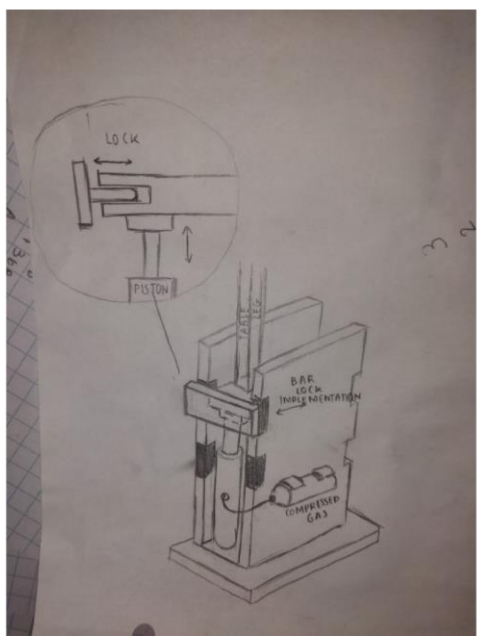

Figure 3: Concept Design 3 containing pneumatic lift, bar lock, and unique table frame design

The following Figure 1 through Figure 3 shows the conceptual designs for the initial scope of the project where a "desk conversion kit" was the prototype to be made.

Table 2: Decision Making Matrix for Previous Scope

Concepts / **Criteria**	Datum (Concept #2)	Concept #1	Concept #3
Performance (ability to lift and withstand weight of desk)	0	0	+1
Safety (meets safety requirements of a desk and does not tip)	0	0	-1
Schedule (how much time and research will be required to produce it)	0	+1	-1
Cost (how much does it cost to make?)	0	+1	-1
Ease of Use (intuitive and easy to use)	0	-1	+1
Aesthetics (does it look good?)	0	+1	+1
Interference with Environment (does it interfere with anything in its surroundings?)	0	+1	+1
Σ+ (Pi)	0+	4+	4+
Σ- (Ni)	0-	1-	3-

Σ	0	3+	1+

Table 2 shows the decision-making matrix used to decide on a conceptual design for the initial scope. The concept that was the best, by comparison, was concept number 1. However, due to the nature of the scope and the concerns that were associated with making the prototype adaptable to any desk size and safe were too difficult. After having external sources review the concept designs, the conclusion was that the concepts developed were impractical and unsafe. As a result, the new scope of creating an adjustable standing table was decided on.

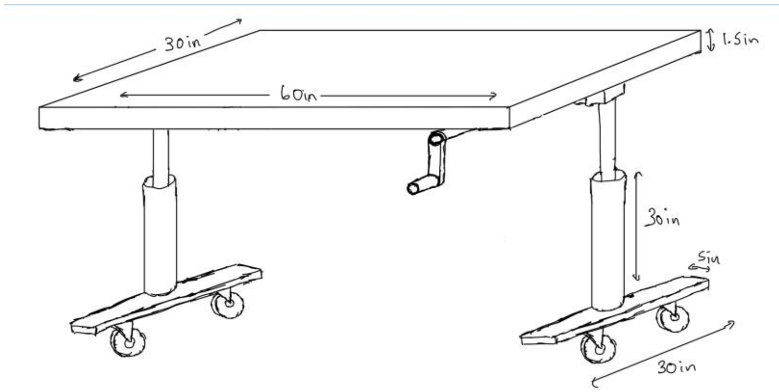

Figure 4: Concept Design 4 containing miter gears, two lead screws, and wheels for a fully functional adjustable table

Figure 4 shows the new concept design developed for the new scope. This was the first design of a fully functional adjustable table made which later evolved into the final design that is seen in this report. The changes made between concept design number 4 and the final design were suggested by an external source who reviewed the concept design and suggested using a single lead screw instead of two.

Mechanical Design

In making and designing the adjustable standing table, the most suitable mechanisms were selected to achieve both basic and auxiliary functions. The main basic functions of the adjustable standing table include the ability to be vertically adjustable and the ability to withstand an external load. The auxiliary function of the table is to be portable and should move freely.

Vertical Motion

To achieve vertical motion in the table, a series of mechanisms and components were used which allow for the adaptation of a hand crank mechanism that converts rotational to linear motion.

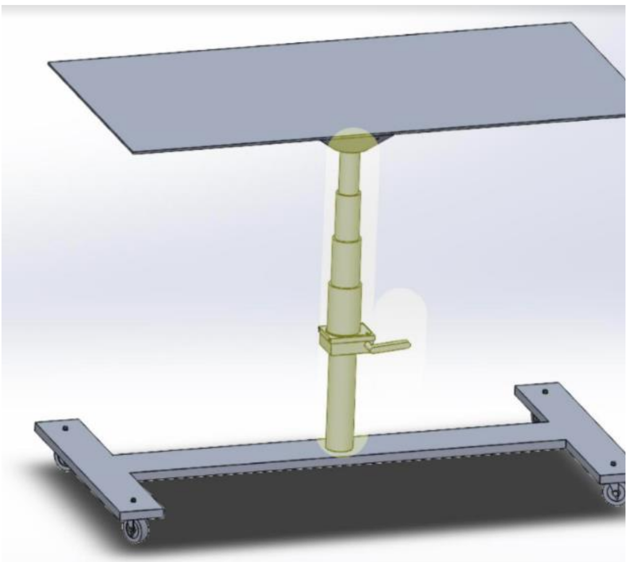

Figure 5: External View of Vertical Lift Mechanism

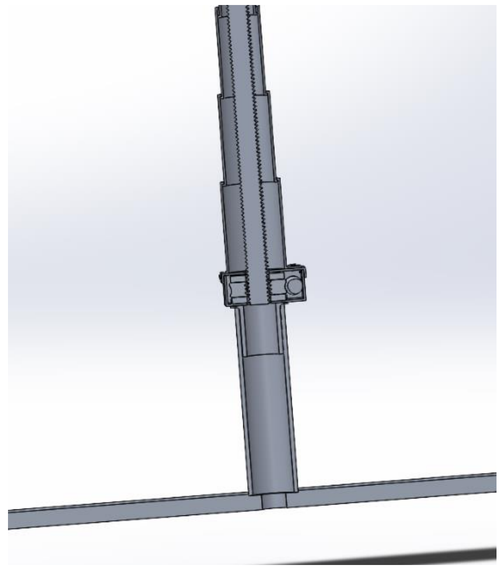

Figure 6: Sectional View of View of Vertical Lift Mechanism

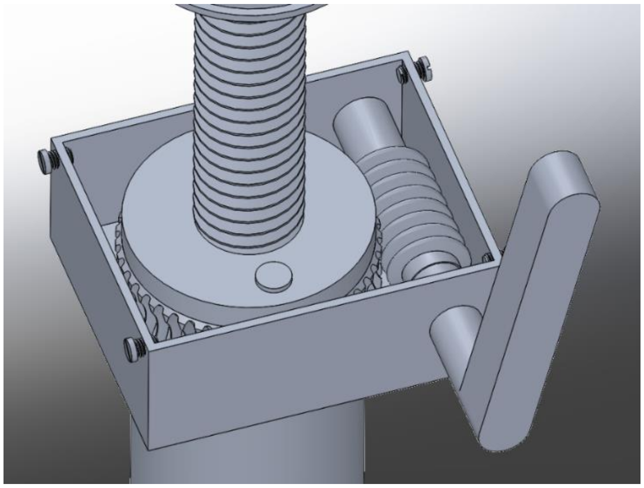

Figure 7: Internal View of Vertical Lift Mechanism

The following Figure 5 through Figure 7 provide external, internal, and sectional views of the vertical lift mechanism for a clear understanding. The vertical lift mechanism developed is a variation of a screw jack (JAES Company, 2019) which involves the usage of a lead screw, worm gear, and worm screw. The use of a screw jack vertical lift mechanism was decided to be the most ideal in this prototype since it is relatively more safe, quiet, and efficient. Screw jack mechanisms require no use of electricity or pneumatics, making maintenance and usage much safer than other mechanisms. As well, screw jack mechanisms are known to be very quiet during operation, making it ideal since the use of a desk is often in places of study or work. By taking advantage of gear ratios and reducing the torque required to operate the lift mechanism, users can easily adjust the height using minimal force.

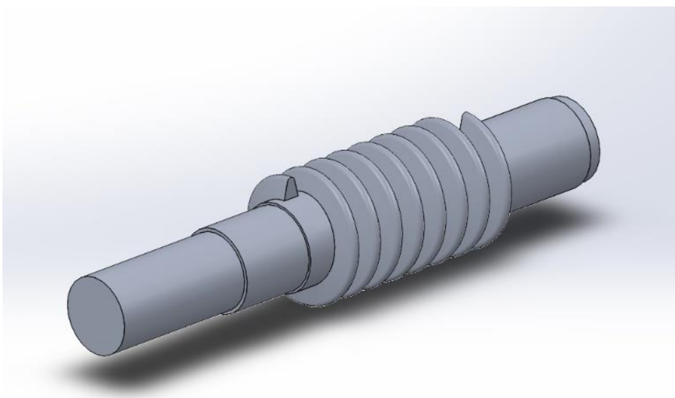

Figure 8: Worm Screw used in converting Rotational to Linear Motion

The worm screw in Figure 8 is suspended by the containing box shown in Figure 7 and is secured in place, disabling motion. The handle/lever is attached to a worm screw which can be accessed from the external of the containing box by the user, also shown in Figure 7. The handle is attached to the hub of the worm screw where there is a threaded hole for a screw fitting. When the user rotates the handle, the worm screw begins to rotate in the same direction as well.

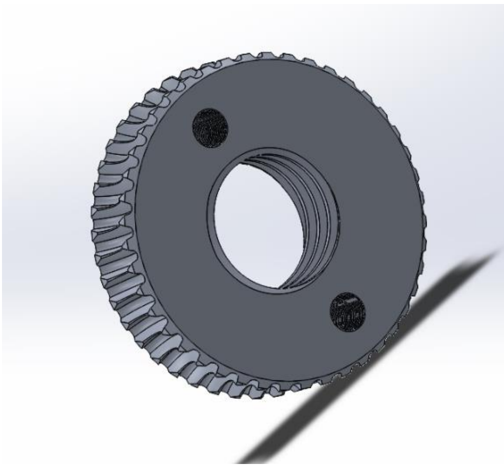

Figure 9: Threaded Worm Gear used in converting Rotational to Linear Motion

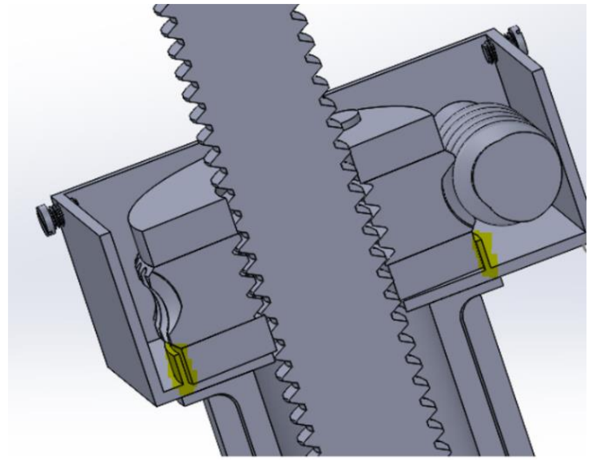

Figure 10: Sectional View of Circular Slot-in Box

Figure 9 shows the worm gear that is also rotated when the worm screw is being rotated. It is important to note that the worm screw has a single-start thread that has a helix angle. As a result of the helix angle, the threads of the worm screw advance the teeth of the worm gear when rotated. This occurs in a gear reduction of 44:1. The worm gear is screwed to a circular metal piece and placed in a circular slot in the containing box to disable translational movement, but not rotational movement, as seen in Figure 10. The addition of grease or oil will help reduce friction greatly during operation.

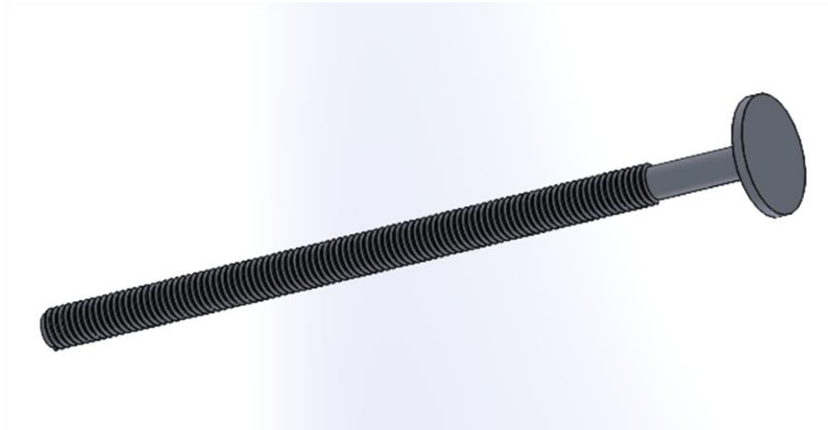

Figure 11: Lead Screw allowing for Adjustable Height of Tabletop

With the threaded worm gear rotating, the lead screw in Figure 11 is also rotated and begins to provide vertical lift or descent (like unscrewing a standard screw, where your screw moves in or out of the threaded hole vertically when screwed or unscrewed). This allows for the tabletop which is fixed to the leadscrew top to be adjusted in height.

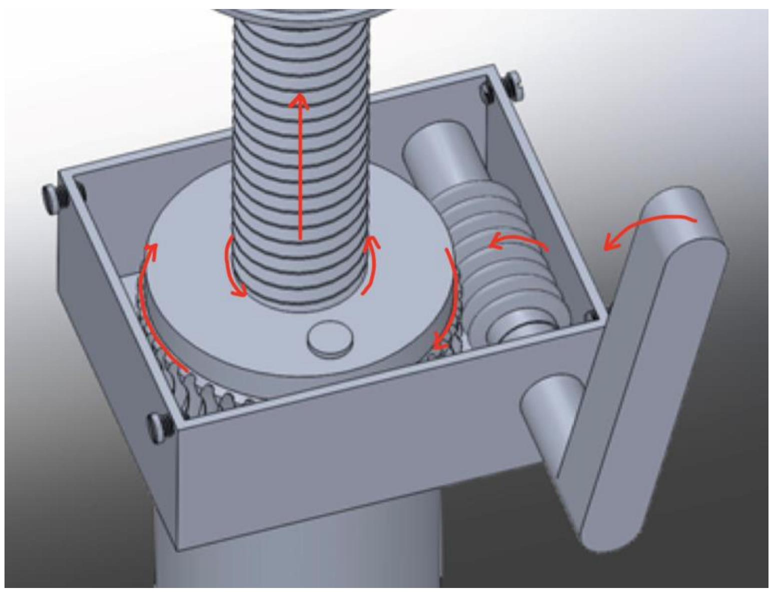

Figure 12: Direction of Motion of Components during Usage

Figure 12 shows the direction of motion of components in the vertical lift mechanism when the handle is rotated counterclockwise by the user.

To accommodate the screw jack mechanism to ensure that the lead screw does not fully disengage from the worm gear, telescopic tubes which are mounted to the tabletop and the containing box are used to bound the adjustable height of the table.

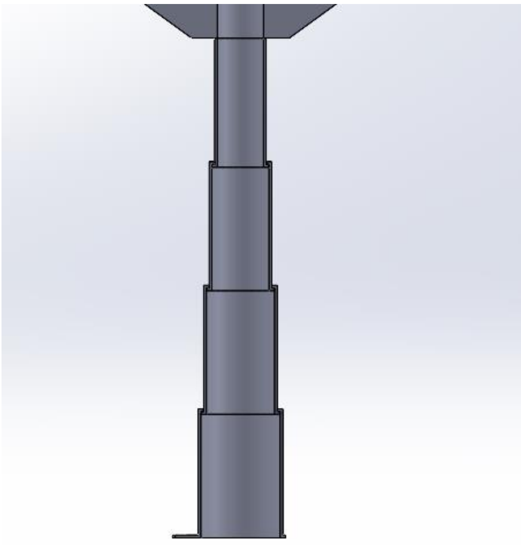

Figure 13: Section View of Telescopic Tubes Extended

To cover the lead screw from exposure, telescopic tubes were created that fit between the box and the conical support. When the table is extended to its maximum height, the telescopic tubes will also be fully extended, as shown in Figure 13. The ridges build into the tubes prevent the desk from over-extending.

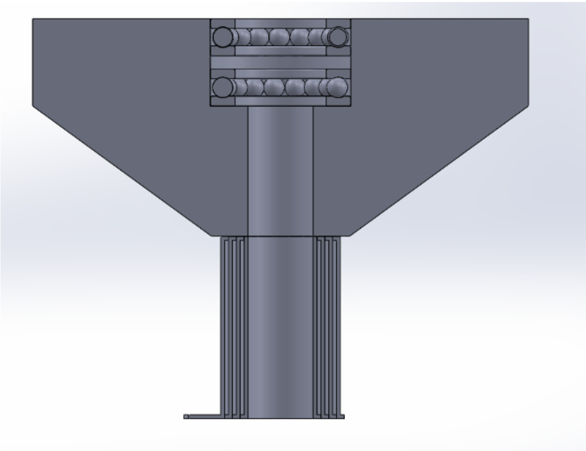

Figure 14: Section View of Telescopic Tubes Collapsed

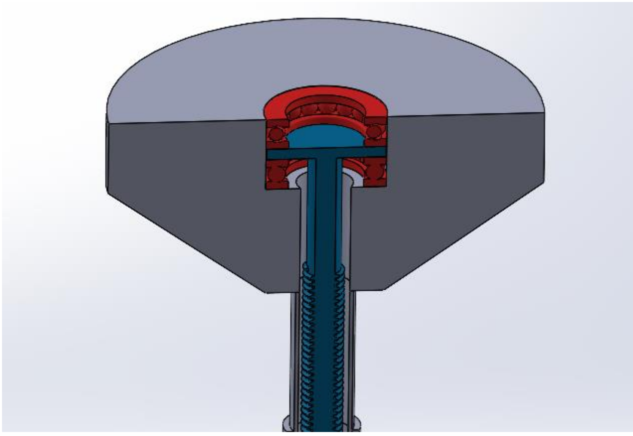

Figure 15: Section View of Ball Bearing and Lead Screw

When the desk is lowered fully, the telescopic tubes will be collapsed, as shown in Figure 14. The tubes will all be supported by the top of the box and will also serve as supports for the table when the table is fully lowered. The final component to ensure the functionality of the vertical motion is met is the use of ball bearings. Ball bearings allow the tabletop to be fixed when using the vertical lift mechanism. Since the lead screw is constantly spinning when the lift mechanism is operating, the tabletop would also spin without the use of ball bearings.

As shown in Figure 15, the head of the lead screw is stuck to two ball bearings, which are both fixed on the other end. This allows the lead screw to spin freely without rotating other parts of the table.

Withstanding External Loads

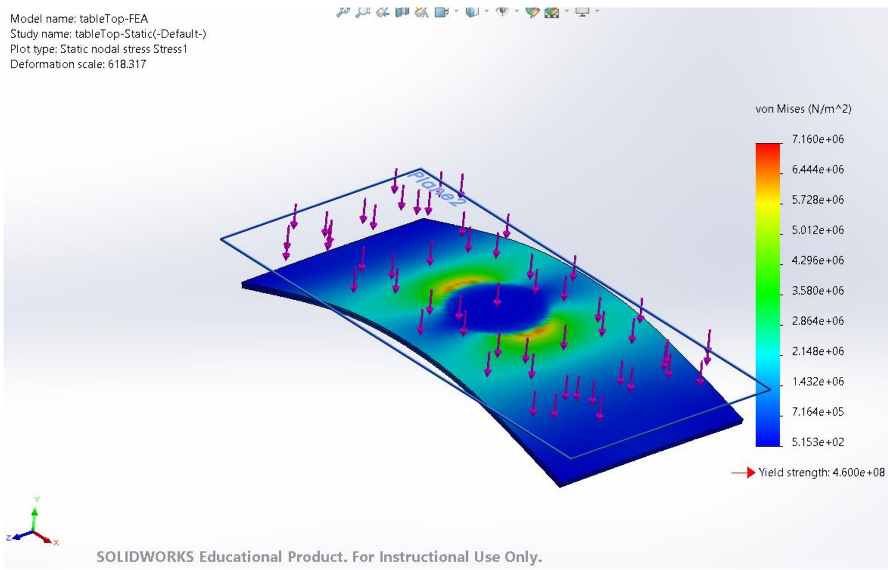

Figure 16: FEA Analysis of Tabletop

Figure 16 shows the FEA simulation done on the tabletop. Similar FEA simulations were done on every other part that would be under the stress of up to 150 kg, not including the mass of the table itself. These simulations can be found (Figure 32– Figure 36) in the Appendix A. To produce an accurate simulation, fixed positions were determined by the component that was attached to the analyzed component. A force corresponding to the sum of the maximum external 150 kg weight applied and the weight of the components above the analyzed part was applied to the top of the part. The mesh size of the simulation was also set so that there would be at least two layers of mesh at the thinnest part of the component. Data such as Poisson's ratio and the elastic modulus were used to create a custom material that matched the physical characteristics of Soda-lime glass, which was used for the tabletop FEA. Aluminum-Alloy (1100-O) was a part of the materials library in SolidWorks and was used as the material for the FEA simulations of the rest of the parts. An FEA was not done on the wheels because the wheels were to be purchased online and the information about them stated that they could support the table and the external load easily (ULINE, 2021). To seek the specifications on these wheels seek the References.

Portability and Ability to Move Freely

Figure 17: Four Polyurethane Caster Wheels attached to Table Base

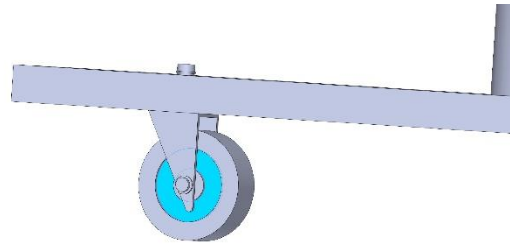

Figure 18: Polyurethane Caster Wheel

Figure 17 shows the polyurethane caster wheel used to support the weight of the desk. This wheel is attached to the table base via a pin and washer that allows its holder to swivel 360° while not detaching from the frame. The wheel is attached to an axel that allows for free rotational movement. The 360° of movement by the wheel holder allows for easy portability of a fully-loaded desk and ease of moving in and out of tight spaces. In Figure 13, the arrangement of the caster wheels is shown, with one placed on each corner of the base for maximum stability and load-bearing capability. Weight from the desk and its contents are distributed throughout each wheel, helping the desk to remain balanced under heavy load. Polyurethane caster wheels are known to be one of the strongest types of load-bearing wheels for this application, holding on around 1000 pounds (453.592 kg) each for the ones being purchased for the following prototype (ULINE, 2021).

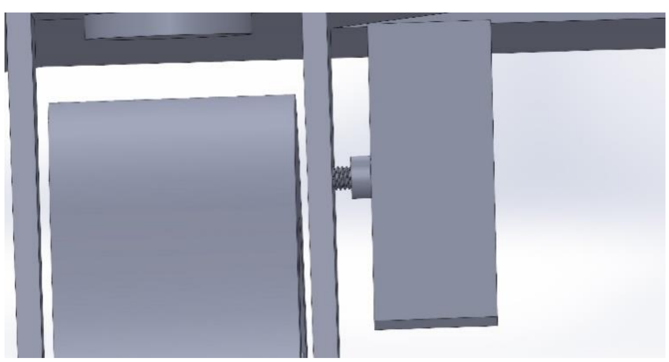

Figure 19: Wheel Lock in Open Position

In Figure 19, the wheel lock is fully unscrewed, meaning there is no friction being placed on the wheel by the screw allowing it to turn freely. The handle which is connected to the screw has been rotated counterclockwise to allow the screw to be removed from the wheel. The wheel lock in this state is in the open position.

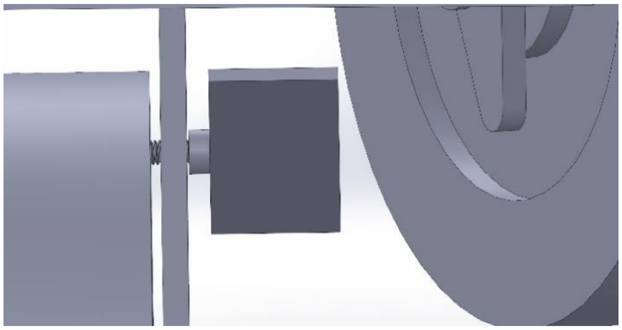

Figure 20: Wheel Lock in Closed Position

Like a piston and caliber in a vehicle wheel disk brake, when turned clockwise the handle in Figure 20 rotates a screw that applies pressure to the caster wheel. When this pressure is applied, the wheel is no longer able to turn freely and is thus locked in position. The wheel lock in this state is in the closed position.

Material Selection

Material selection was done using the GRANTA EduPack 2020 Software (Granta Design, n.d.). When selecting materials, typical material properties used to make the specified components were analyzed and compared. Selected materials maximize or minimize the desired characteristics and ensure that the engineering specifications specified are met.

When selecting materials for the table frame and components, the favorable characteristics were identified to maximize performance and user experience. These characteristics include the ability to withstand the weight of maximum load, be self-supporting, be light weight, and be easy to manufacture.

Table 3: Material Properties for Possible Table Frame and Component Materials

	Low Carbon Steel	**Aluminum-Alloy (1100-O)**	**Better Choice**
Compressive Strength	255 MPa - 355 MPa	245 MPa – 521 MPa	Low Carbon Steel
Cross-Sectional Area Required to withstand Max Compressive Force	$5.771 \times 10^{-6}\ m^2$	$6.006 \times 10^{-6}\ m^2$	Low Carbon Steel
Density	$7.8 \times 10^3\ kg/m^3$ - $7.82 \times 10^3\ kg/m^3$	$2.67 \times 10^3\ kg/m^3$ - $2.84 \times 10^3\ kg/m^3$	Aluminum - Alloy
Price	1 - 1.04 CAD/kg	5.58 - 5.9 CAD/kg	Low Carbon Steel
Castability	3	4 - 5	Aluminum - Alloy
Machinability	3 - 4	4 - 5	Aluminum - Alloy

The following Table 3 displays the material properties (Granta Design, n.d.) for low-carbon steel and aluminum alloys, two common materials used in making table frame components like the one in this prototype.

$$F_{compressive} = (m_{max})(g) = (150kg)\left(\frac{9.81m}{s^2}\right) = 1471.5N \tag{1}$$

Where $F_{compressive}$ is the maximum compressive force experienced by the table, m_{max} is the maximum load placed on the table, and g is the gravity at sea level.

Using Equation 1, the maximum compressive force used (based on the maximum load the table will carry according to engineering specifications) is calculated to be 1471.5N.

$$A_0 = \frac{F_{compressive}}{S} \tag{2}$$

Where A_0 is the cross-sectional area required to withstand the maximum compressive force, $F_{compressive}$ is the maximum compressive force experienced by the table, and S is the compressive strength of the material.

Using Equation 2, the cross-sectional area required to withstand the maximum compressive force imposed on the table (or row 2 of Table 3) can be calculated. It is important to note that the lowest possible compressive strength (worst-case scenario where the material used is easiest to deform under compressive force) provided in the range was used to derive this cross-sectional area. After conducting these calculations, it is obvious that both materials are qualified to be used since they are both require almost a negligible cross-sectional area to withstand the maximum compressive force. As a result, the decision was made placing more emphasis on other material properties.

Aluminum-alloy (1100-O) was selected to be the material of the table frame and components since it is lighter, and more manufacture friendly (which is very important since many of the parts used in the table are custom parts). Although Aluminum-alloy is more expensive, its materials properties prove to be more suitable for the following prototype and as seen in Verification of Design, the price of the table as a prototype is still below the maximum specified cost.

Favorable characteristics when selecting the tabletop materials include the ability to withstand maximum load, be lightweight, be scratch resistant, and be aesthetically pleasing (Room&Board, n.d.).

Table 4: Material Properties of common Tabletop Materials

	Hardwood	**Granite**	**Soda-Lime Glass**	**Better Choice**
Compressive Strength	12.8 MPa – 15.6 MPa	110 MPa – 255 MPa	310 MPa – 340 MPa	Soda-Lime Glass
Density	$850 \times 10^3\ kg/m^3$ - $1.03 \times 10^3\ kg/m^3$	$2.63 \times 10^3\ kg/m^3$ - $3.2 \times 10^3\ kg/m^3$	$2.44 \times 10^3\ kg/m^3$ - $2.49 \times 10^3\ kg/m^3$	Soda-Lime Glass
Price	8.94 - 14.4 *CAD/kg*	1.39 - 8.31 *CAD/kg*	1.88 - 2.22 *CAD/kg*	Soda-Lime Glass
Hardness (Vickers)	10 - 12.2 *HV*	27 - 45 *HV*	439 - 484 *HV*	Soda-Lime Glass
Safety Concerns	None	None	Glass can be tempered to reduce shattering and increase strength	N/A
Aesthetic Concerns	Colour changes with age, humidity contraction. Scratches are visible, heat and moisture damage	Can stain. Chip or scratch with heavy use	Fingerprint sensitive, glare and direct light	N/A

Material properties displayed in Table 4 (Granta Design, n.d.) were compared to decide that soda-lime glass was most suitable for use as a tabletop material. Its low price and density allow for it to be lightweight and cost effective as needed. As well, its hardness numbers on the Vickers scale proves that it is extremely scratch resistant. With the ability to be tempered to enhance properties even further such as compressive strength and to reduce shattering when broken, soda-lime glass is a perfect fit to be used as a tabletop (Room&Board, n.d.).

Since there are only two major types of caster wheels (rubber or polyurethane) commonly used in tables today, the benefits and characteristics of each one was compared to select the most ideal one. The favorable characteristics of a wheel were determined to be the ability to bear the maximum load, scratch resistance on floor surface, roll resistance, and cushioning and resilience (ability to absorb the vibration/energy from uneven floor surfaces). After analyzing these characteristics, polyurethane wheels were decided to be the best fit since they can withstand up to 1000 pounds on a single wheel (the prototype has 4) and they are less roll resistant (due to the nature of the material being harder as opposed to the softness of rubber). Although softer materials such as rubber benefit greatly in cushioning and resilience compared to harder materials such as polyurethane, the table is intended for indoor use (where the floor is almost always even), making polyurethane wheels perfect for use (ESSENTRA Components, 2019).

Ergonomics

When considering the mechanical design of the prototype it is important that there is consideration of the characteristics of the user and how the user will interact with the prototype. For this, common dimensions and anthropometric charts were consulted for the best user experience.

The average sitting height of a desk is about 30 inches and after consulting anthropometric data, the resting elbow height in standing position is about 46 inches to account for male users just above the 97th percentile (which is equivalent to accounting for female users over the 99th percentile). The 97th percentile data was selected since most consumer products account for the 95th percentile. As a result, the lower bound was selected as 30 inches and the upper bound was selected to be 46 inches in adjustable height (Gordon, 1988).

Table 5: Common Tabletop Dimensions

Dimension Number	Dimensions	Area
1	48 in x 24 in (1.2192 m x 0.6096 m)	0.74322432 m^2
2	60 in x 30 in (1.524 m x 0.762 m)	1.161288 m^2
3	72 in x 36 in (1.8288 m x 0.9144 m)	1.672254712 m^2

The dimensions of the tabletop were selected based on common table sizes as seen in Table 5. Further investigation into the current market of adjustable standing tables led to the confirmation that 60 inches by 30 inches was the most common size. For this, 60 inches by 30 inches was selected as the tabletop dimension (Randel, 2015).

Safety

There were numerous characteristics and mechanical design decisions made to maximize the prototype's safety during its usage. By eliminating the usage of any electricity and ruling out many vertical lift mechanisms that involve the usage of motors or pneumatics, the safety issues that come with them such as electrocution or the explosion of compressed gas are also eliminated. As well, putting a locking mechanism on the caster wheels disallow movement and increase safety especially if the user has children. As seen in Verification of Design, tests conducted ensure that the components can withstand the maximum load (and loads slightly over the maximum load) to ensure that the prototype will not break or deform. To ensure further safety, the tempering of the soda-lime glass tabletop can provide a stronger compressive strength and hardness to combat issues such as withstanding even greater loads or being more scratch resistant in the case of heavy-duty work (Room&Board, n.d.). When tempered, the glass becomes very shatter resistant and when broken, does not shatter like typical glass does and instead, will stay intact (similar to car windows) increasing safety greatly if the table were to break.

Verification of Design

Engineering Specification #1 and Verification

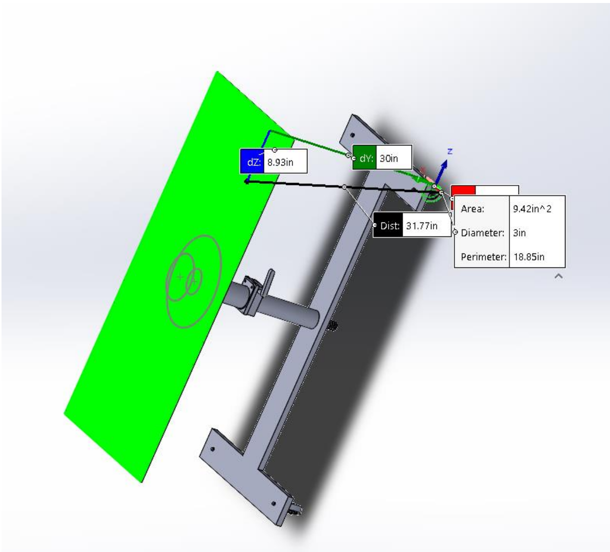

Figure 21: Height measurement of table from Ground to Tabletop in Fully Reclined Position

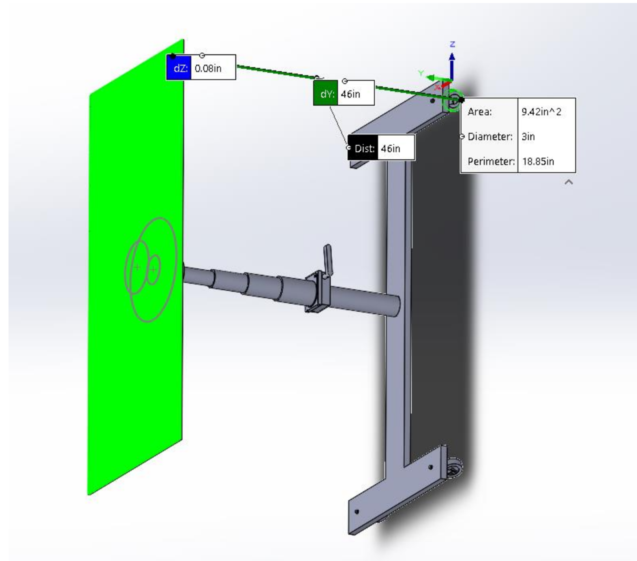

Figure 22: Height measurement of table from Ground to Tabletop in Fully Extended Position

To verify that the table can be elevated to a desired standing height between 30 and 46 inches (inclusive), the analysis verification method was used. Using the 'Measure' function under the Evaluate tab of SolidWorks, a direct measurement from the ground to the tabletop (in fully extended and fully reclined position, as seen in Figure 21 and Figure 22) was taken to verify that the range of adjustable height was between the specified range.

Engineering Specification #3 and Verification

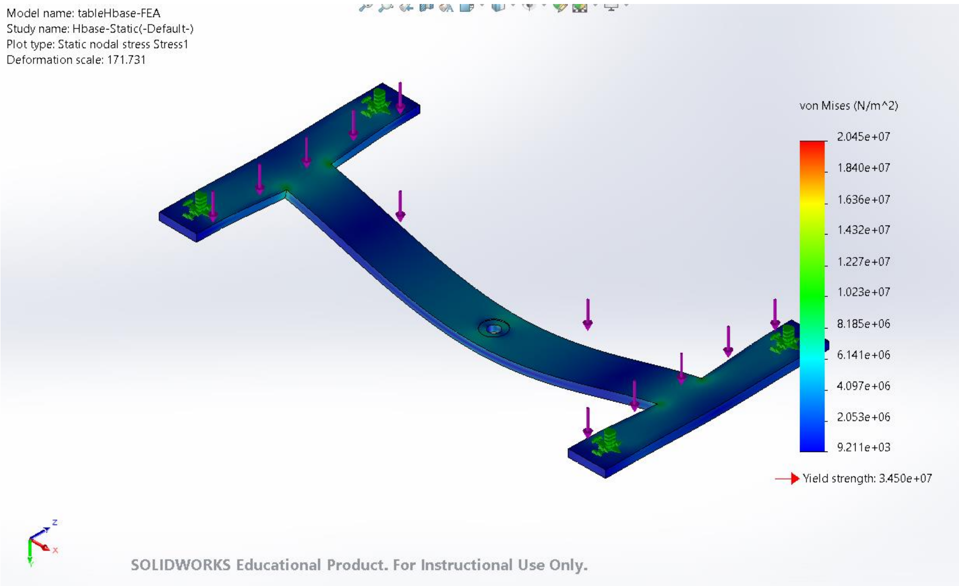

Figure 23: FEA Analysis of H-Base

To verify that the table can withstand up to a 150 kg weight, FEA simulations are used to determine whether the components will break, as shown in Figure 23 above, as well as Figure 16, Figure 32, Figure 33, Figure 34, Figure 35, and Figure 36. Due to the yield strength being greater than maximum value on the von Mises scale for every component, the maximum stress applied will not cause plastic deformation, thus demonstrating that the table can withstand a 150 kg external load.

Engineering Specification #4 and Verification

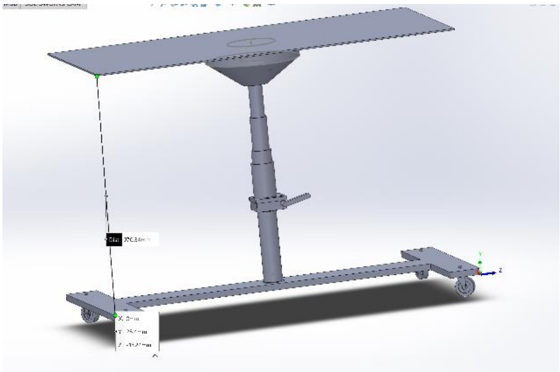

Figure 24: Table Level Measurement Left Side

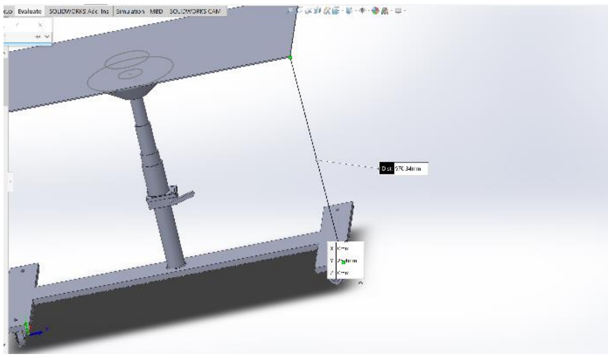

Figure 25: Table Level Measurement Right Side

To ensure the desk would not tilt more than 5 degrees, measurements are taken from the tabletop to the base in two identical locations and checked for equality. In Figure 24 and Figure 25, the measurement reads 970.34mm meaning there is no tilt because the tabletop possesses the same height on either side. Although difficult to show the levelness of the tabletop design, once completed, a level can easily be used to check the degree of tilt. However, all SolidWorks parts are designed to be straight with 90° edges, so all parts put together, in theory, have no tilt.

Engineering Specification #5 and Verification

To verify that the table does not make noise during adjustment and operation, the examination verification method was used. By inspection, it is evident that the prototype does not require the use of electricity and does not use any electrical equipment or pneumatics which might cause noise during operation. This proves that the table is quiet during adjustment.

Engineering Specification #6 and Verification

To verify that the table costs less than 1000 CAD (which is the competitive market price for a similar standing table today) to produce, the analysis verification method was used.

Table 6: Cost Analysis of Table Prototype

	Cost
Table Frame and Components	(65.055 *kg*)(5.90 *CAD/kg*) = 383.83 CAD
Polyurethane Caster Wheels	(4 *wheels*)(41 *CAD/wheel*) = 164.00 CAD
Glass Tabletop	(18.122 *kg*)(2.22 CAD/kg) = 40.23 CAD
Machining Labour Costs	Up to 250 CAD (but may vary slightly since parts are custom and it is hard to estimate without getting a quote)
Subtotal	Up to 838.06 CAD
Total	Up to 947.01 CAD

Table 6 shows the cost analysis and expenses to manufacture a single prototype of the adjustable standing table. As seen, the price to manufacture a prototype is less than 1000 CAD, thereby verifying the engineering specification. It is important to note that it is very likely that is much cheaper to mass manufacture the following prototype, putting it at a competitive price point in the market if it were to be sold alongside its counterparts.

Engineering Specification #7 and Verification

To verify that the following prototype is easy and intuitive to use, a test was conducted as the verification method. The test consists of a survey asking users to identify how to operate the table in under 5 minutes and at least 80% of the participants must be able to do so.

Figure 26: Photo Sent to Participants

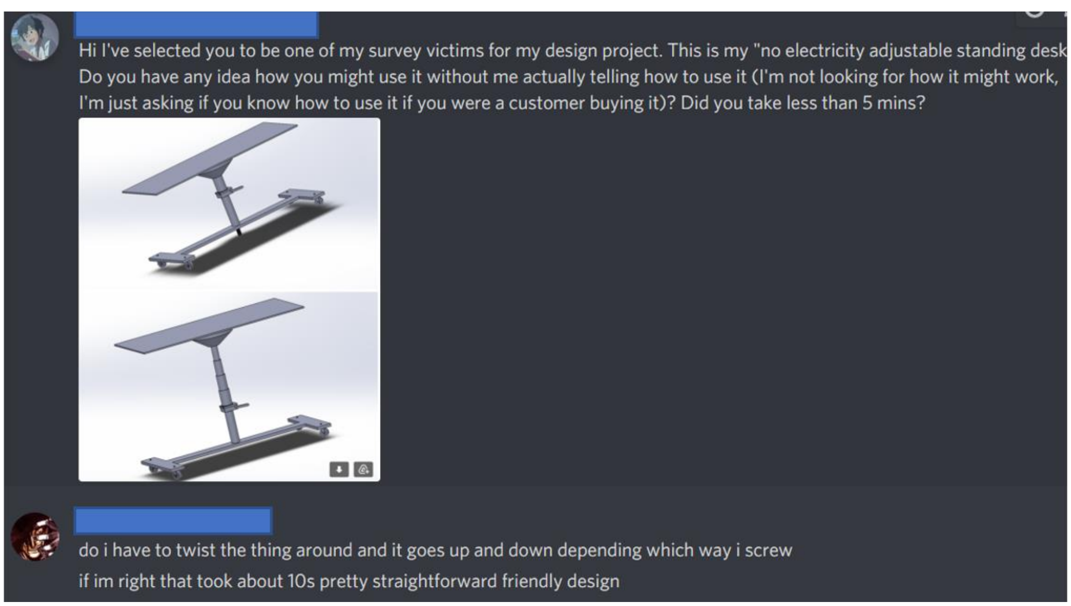

Figure 27: Example of Unbiased Survey Prompt

Figure 26 is the photo that was sent alongside an unbiased prompt to a sample size of 20 participants. An example of the unbiased prompt can be seen in Figure 27 where the prototype is labelled as a “no electricity adjustable standing desk”; like what it would be marketed as.

Table 7: Time Taken to Figure out How to Operate the Prototype

Less than 5 Minutes	**Greater than 5 Minutes**
18	2

Table 7 represents the findings of the survey and 90% of the participants were able to identify how the table operated without any instruction. This proves as a success and engineering specification number 7 is verified.

Engineering Specification #8 and Verification

Figure 28: Standard Desk

Figure 29: Standing Desk Final Design

To verify that this desk design does not interfere with normal desk use and function, four distinct features were identified and compared through demonstration. Leg room, movement and portability, dimensions and tabletop obstruction are compared. By also choosing a base desk to analyze in Figure 29, the comparisons can be made visually. Leg room is generally the same between both examples except for the center table leg in the final design. While this does technically take away space from the user, most do not rest their feet in the center of the space but rather to each side. The movement and portability of this desk design is identical to most standard desks. Four wheels allow to desk to move in any direction while the vertical motion assembly moves the tabletop to the desirable standing height in a way like other designs by using a handle. Standard desks were an influence while brainstorming and deciding upon the movement of this final design. Desk dimensions stated above are based on that of a typical desk and adhere to the ergonomic recommendations made for any desk in development. Finally, no tabletop obstruction is ensured since all available surface area of the tabletop is clear for use. Being of a centered lead screw design, freeing the tabletop from obstruction meant redesigning the vertical motion assembly so the lead screw did not have to penetrate the table surface while fully contracted

Project Management

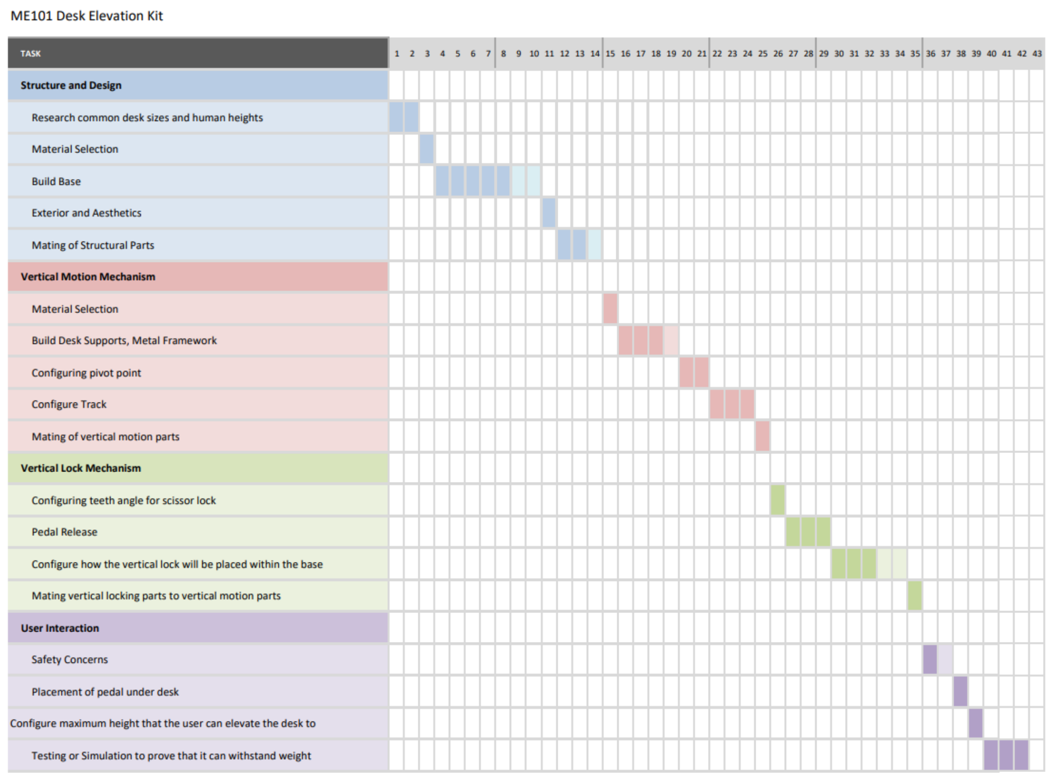

Figure 30: Gantt Chart of Desk Elevation Kit

The initial timeline for the project is shown in Figure 30. The first stage of the timeline is to build the exterior and choose the materials for the desk elevation kit. The next stage is to build the vertical motion mechanism and the third is to make the locking mechanism for the kit. The final stage is to add the features that allowed the user to elevate and lower the desk. However, after the first design review, it was decided that a desk elevation kit was impractical to create. Therefore, the project was altered to create an adjustable desk.

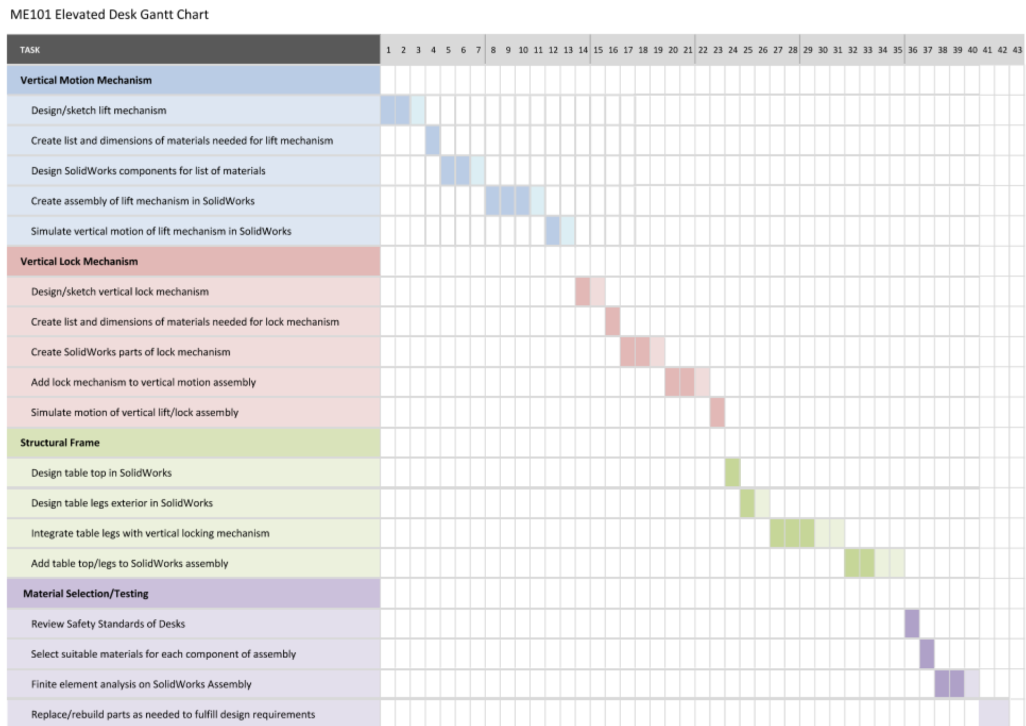

Figure 31: Gantt Chart of the Adjustable Desk

The current timeline of the project is shown in Figure 31 The time period for project completion remained the same and there were still 4 different components of the project, but these components changed to vertical motion mechanism, vertical lock mechanism, structural frame, and material selection/testing. Tasks were split among group members based on the different subsections of the Gantt chart. The timeline was altered to have different group members work on their respective subsections simultaneously because the subsections were not dependent on each other.

Conclusions

The objective of this design was to elevate a desk or working space to a desirable standing height while meeting certain safety requirements and regulations of a typical desk. The aim of this design was to help combat the back and posture issues caused by excessive sitting, faced by many over the course of the pandemic. To meet this aim, the design uses a unique screw and gear assembly with worm gears and a lead screw, along with telescoping tubes to achieve vertical motion. This allows the desk to be raised and lowered with the simple turn of a handle while spreading out weight evenly and being stable under heavy load. The collapsing telescoping tubes are an exclusive part of this design that keep the desk stable while elevating and descending by keeping the lead screw securely in position. Also, this design features a unique base to maximize leg room for the user while still evenly distributing weight amongst four polyurethane caster wheels. To ensure the desk met all safety, cost and ergonomic requirements, extensive testing was completed. After collecting data, surveys, and test results, it is concluded that this design overall meets the set of requirements. The design proved its safety through numerous load tests and an FEA where yield strength was obtained and analyzed. Through surveying and statistical analysis, it was determined that this design adheres to all dimensions for the optimal desk height and size while being easy and intuitive to use, taking the average user less than 5 minutes to understand with no instruction. Cost was kept to a minimum by keeping a total receipt of all parts used to ensure the product can be affordable for the average user. This standing desk concept survived major changes and countless small iterations to come together as the final design presented in this report, improving health conditions of many who recently fell victim to excessive sitting.

Recommendations

A possible recommendation is to retain the initial concept number 4 design. Although suggested by an external source that reviewed the concept design to minimize the number of lead screws to one, after further developing the prototype, there was a need to create a more convenient leg space when using the table. Many tables have two supporting table legs which not only increase the stability and reduce fracture probability, but also provide a more comfortable place to sit with legs tucked in. With single lead screw in the middle, one must sit with their legs in an unnatural position to use the table.

Another recommendation is to simulate non-uniform weight distributions in the FEA simulations in SolidWorks, which would make the simulation more realistic. This would then be a more accurate way of ensuring that the engineering design specification #3 was met.

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Appendix A – FEA Simulations of Table Components

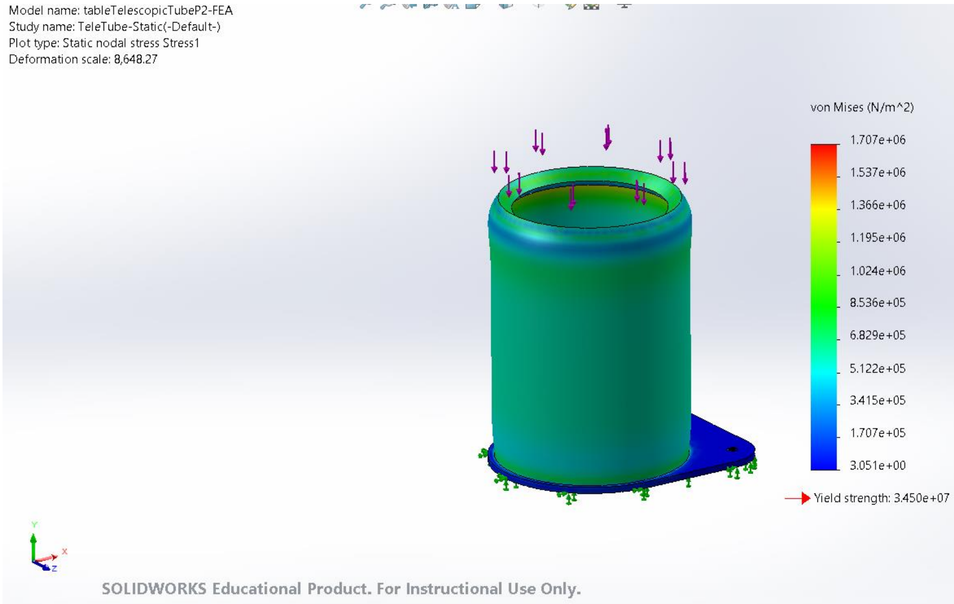

Figure 32: FEA of a Telescopic Tube

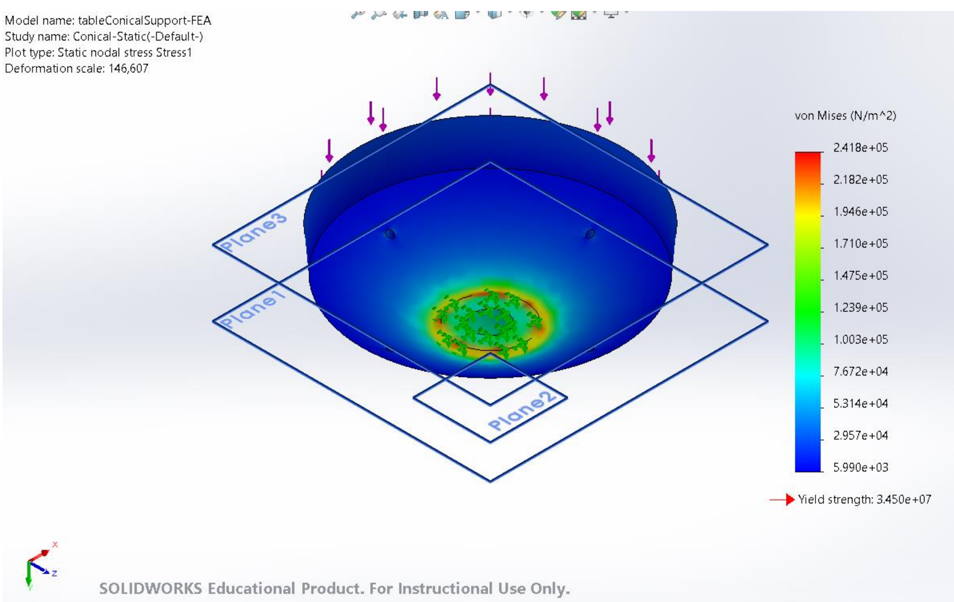

Figure 33: FEA of the Conical Support

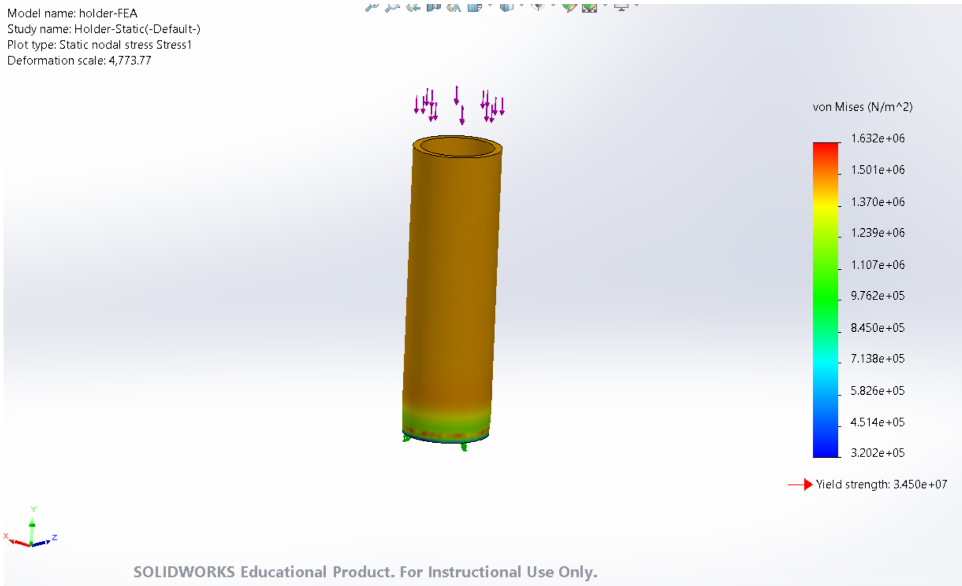

Figure 34: FEA of Lower Tube

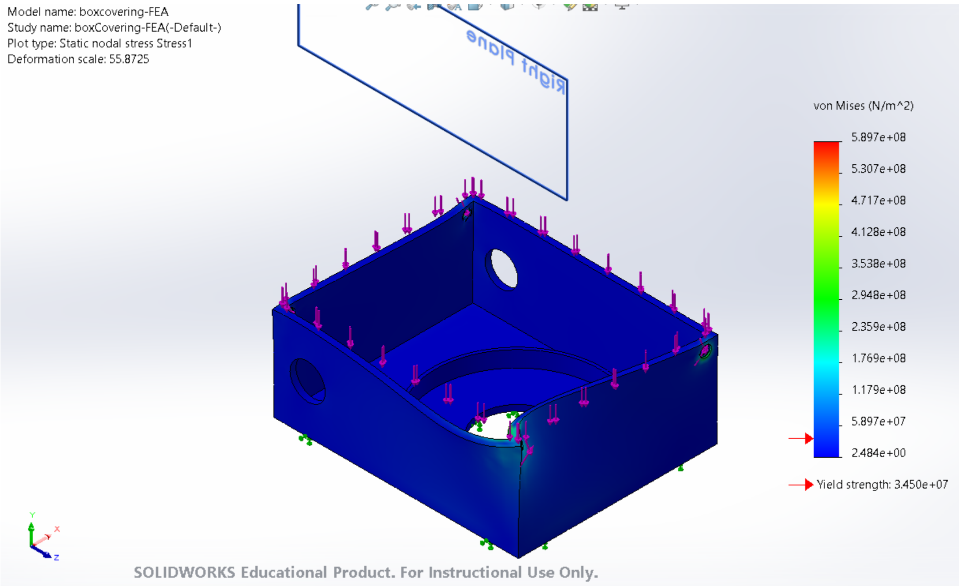

Figure 35: FEA of Box Covering

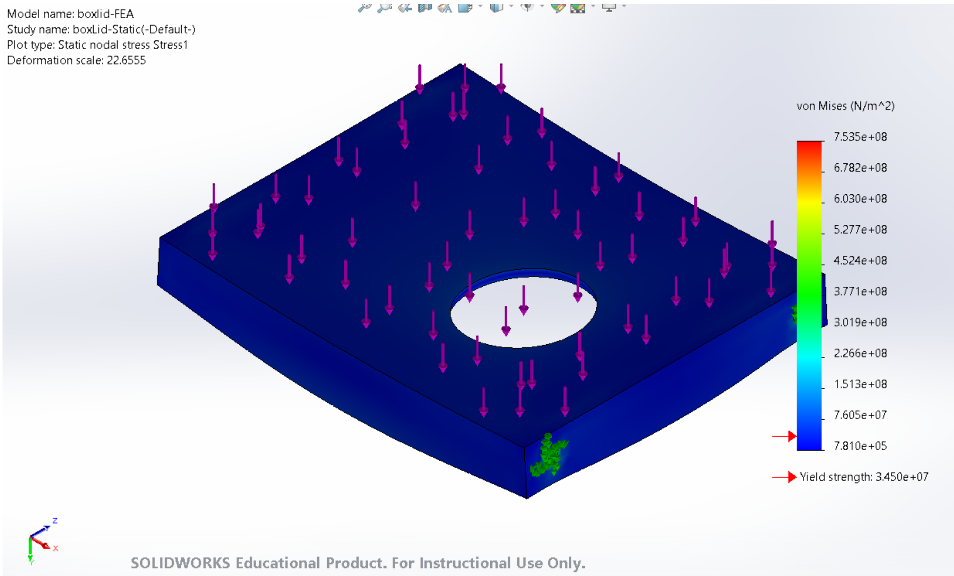

Figure 36: FEA of Box Lid