EASELECTRIC
Optimal Design

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Client Contact: Brook Hallowell, NSF
Introduction

The goal of this project is to design an easel that is electronically adjustable and that is safe and easy to use within a community of cognitively impaired individuals. The easel is required by our sponsor NSF, specifically Brooke Hallowell, to be light-weight and easy to store when not in use, and be able to move in various directions. Some of the effects of cognitive impairment are that our client, Harry Grim, has limited dexterity and limited arm movement. We have designed an easel according to these specifications and are confident that Harry Grim will be pleased with the outcome of his new easel.

Design

Our easel is electrically controlled by two detachable joysticks which allow the operator to move the easel in three different planes. Each joystick moves the easel in four different directions. We decided to use two joysticks instead of one, because the devices have to be easy for Harry to use. If there are too many directions on one joystick it might be difficult to reach the desired positioning of the easel. The joysticks control relays and this allows for the easel to move up and down, left and right, front to back, and also tilt. Once the user makes an input of which way they would like the easel to move, the easel will respond having the base and carriage subunits make the request movement.

The first action taken to begin a well developed design for our electrically adjustable easel involves a block diagram which states the basics as to what the project must do. This involves an easy set up, elementary styled controls for user input, dynamic movement of the easel, and a basic electrical flow diagram.
The design will essentially be a base attached to a series of aluminum frames made of angle, channel and tubing pieces, and a base to attach to the table that the easel is seated on. The under-part of the design will be clamped to the table with a screw clamp for added stability so the easel is sturdily attached to the table while the client is painting and to accommodate for different sizes and shapes of tables. The base and carriage will sit on top of the table and each will be responsible for splitting up the different motions which the easel will perform. The tilt of the easel will be operated by a linear actuator.

There are multiple safety features that our design includes. We are making sure that all the wires are safely attached and not exposed to anyone who might be tempted to tug or pull them out. We have also included a master on/off switch that will allow a supervising attendant to decide when the operator is done or in case of an emergency. This switch will be placed in the back of the easel so that it is not easily accessible to people who aren’t authorized to use it. We have also ensured that the movement of the easel itself is not too fast with the actuators or that it will overextend beyond its maximum range and fall off the tracks. This is done through the use of limiting switches.

Our easel has many advantages. It will be designed to be able to fold down after use and stored away without being bulky and in the way. Our easel will be built mostly from aluminum channeling and square tubing which can also be considered an advantage because aluminum is a good design material providing it is cheap, lightweight, and sturdy abilities.

Dimensions

Visio diagrams of the project are seen below. The easel face from our second design has been decided to be the optimal design to support the canvas, with the least mass. Steering away from the classic “A” frame model of an easel stand, here, 1” x ¼” flat-stock aluminum will be used to construct a more “H” styled easel frame. The top clip will be adjustable ranging from 9” to 24”. The bottom lip will support the canvas securely, supporting a reasonable canvas width (no greater than 40”). ¾” diameter drill holes will provide one inch adjustments, allowing for a wide range of intricate canvas sizes. The supporting screws will be easy to tighten wing nuts. Again, since the type of canvas may differ from painting to painting, a diversely supportive easel frame must be able to accommodate all different types of canvas styles. Our design has accomplished this goal. A diagram of this new style is seen on the next page:
The primary dimensions have not altered too dramatically from the first design. However, many differences have been made in the assembly and certain motion procedures. Front to back motion will now take place along two 3” angle pieces welded to the base and will attach to a carriage frame of 2” angle and channel pieces. Sliding tracks will allow the two sets of angle pieces to slide smoothly and securely along the 6 inch travel length. The 22” vertical columns will be made of 1” x 2” rectangular tubing, hiding wires within. Two 17” aluminum glide bars will allow for sturdy vertical movement of the easel. The vertical tubing pieces will tilt along hinges or a pin system that will be discussed later in the report. A figure of the front view of the easel (minus the bracket and easel face) is seen below.
The actuator controlling vertical movement will be concealed by a 1” x 2” channel piece. Horizontal movement will proceed via a screw drive fastened securely within the aluminum tubing piece riding along the 17” glide bars. The side view of the easel is seen on the following page.
In our optimal design, we have decided that keeping the same clamping technique from the first design is the best way to support the easel and secure it to the table. The dimensions of the table being used at Passionworks® is unknown, and this setup will accommodate a variety of table sizes and shapes. As shown in the side view, the clamps will reach one foot under the table, which was decided an acceptable length so that the supervisor will not have to strain themselves to tighten the clamp. The screw assembly will consist of a 6 inch long, ½ inch diameter threaded rod that will screw through a 1 inch hexagonal nut welded to the under arms. These arms are composed of 1”x 1” angle pieces, 12 inches long that are then welded to ¾” square bar. The square bar will be able to adjust 5 inches within the base, and will fit nicely into 1” aluminum tubing pieces cantilevered over the side of the table vertically. Pins will allow the arms to adjust to a
variety of lengths, preventing limitations of any unaccounted lips or obstructions that are fastened to the table. Below is a diagram of the upper carriage of the easel, dimensioning parts hidden behind parts of the easel’s frame.

As shown, the bottom angle piece attaches to the actuator controlling front to back movement, which in turn is attached to the base of the easel. The tilting actuator is connected at two pins to adjust and rotate efficiently for specified angles the easel face will have. The bracket for the easel face is also seen here, which will connect to the screw drive controlling horizontal movement. This bracket will consist of two, 3” long aluminum plates and another 2” plate normal to the horizontal.

Linear Actuators

The first design calls for three linear actuators. From mechanical assessment of the easel, these actuators should support loads no less than 20 to 30 lbs. The movement of the actuators should consist of a slow speed, one of the requirements of the project. The actuators will work in three different planes; one horizontal to move the carriage of the easel back and forth, one vertical to raise and lower the easel face, and one connected through a diagonal plane connected by bolts to tilt the carriage at desired angles. Each actuator has been assigned to have a total adjustable length of 6”. This value has been determined through careful analysis to provide sufficient movement of each part without risking injury to the artist by moving the easel too far. The actuators will be powered through a circuit controlled by joysticks, and wired safely through aluminum tubing, preventing anyone to mistakenly tamper with the wiring.
Currently, the linear actuators under consideration are 6” Linear Actuators. Their cost is roughly $44.95 a piece. They travel at a speed of 1/3” per second, which has been assumed a relatively acceptable speed for an operator with delayed reaction time. A 12 vdc nominal voltage is required for a push/pull force of 165 lbs. Although this value is a bit excessive, it will account for loads greater than expected (i.e. if someone was to sit, or hang a heavy item from the easel, there is less of a probability of mechanical failure). These specific actuators include an IP54 rating, regarding splash and dust resistance. The 2-wire harness inside provides reverse polarity to change direction and built in limit switches to prevent the easel from moving past maximal points of excursion. Their aluminum design will also match the aluminum frame of the easel.

For the horizontal displacement a screw drive will be used. This allows the easel to move as far left or right as we want. The drive that the rod will rest on will be fabricated to our specified dimensions.

**Drawer Tracks**

Only one set of tracks will be used in this project which will be used for the front to back motion between the carriage and base of the easel. These tracks will be welded securely to frames consisting of 3 inch and 2 inch aluminum angle. The maximal excursion for front to back movement is limited by the range of motion of the actuators, which is 6”.

The tracks under consideration are Dynamic NT Self-Close Full Extension Drawer Slides, which maintain a load rating of 100 lbs. at full extension (9 inches). By securely fastening or welding these tracks to the angle iron supports, we will achieve a very sturdy forward and back motion for the easel.

**Mechanical Design**

The base of this design must maintain sturdy and solid principles while the easel is in motion. As specified by our contact, a table top design will be best suited for the needs of the client. A problem arises as to the dimensions of the table. In order to provide an easel that will work properly, the base should adjust to fit tables of different dimensions, shapes, and locations. The design of the extending arms which will clamp the base to the table have been designed to properly match the above criteria. By designing the arms to go under the table rather than to the sides will allow the easel to be used on tables propped against walls or in cluttered, space limited areas. The base is also designed for different table shapes, allowing not only square or rectangular surfaces to be clamped, but also circular or oval shaped tables. The width of the table was the most important feature of the clamping mechanism to consider. The screw clamp will adjust to widths of zero to six inches. Using the adjustable cantilever allows the arms to slide up and down, providing movements around any possible lips or overhangs of the table unaccounted for. Mechanical analysis of the clamp and base will be considered next.

1. **Clamp**

One of the most important components of the device is how it is secured to the table. Without a robust system to attach the easel to the table, there is an enormous risk of injury to the user due to a large moment created by the full extension of the drawing
surface or misuse. In order to handle this moment, a strong frame constructed of one-inch square aluminum tubing is used which capable of handling a maximum stress of 4,000 psi (Figure 5). As can be seen in “Static Analysis of Clamp Under Own Weight,” under normal operating conditions these features are under nearly no stress due to the extreme light-weight properties of the Aluminum, it is only under misuse that their mechanical properties are tested. The clamp is designed to be adjustable to accommodate tables with varying lips and extends and clamps via a threaded screw 16 inches under the table, allowing it to counteract any large moment arms placed upon the device by misuse.

The weight of the clamp, located at the centroid, produces a small moment of only 3.92 lb-in and is exposed to a downward force of 0.87 lb, producing a shear of 8.86 psi in the pin connecting the clamp to its receptacle in the base. Under normal operating conditions, the weight of the carriage and drawing surface are directly over the table to which the easel is attached, meaning that the load is handled by the base and transmitted directly to the table. This direct transformation of load means that no additional moment is transferred to the clamp during the majority of the operating time resulting in a factor of safety in the clamps of around 1700.

As can be seen in figure 5 and the Static Analysis, the clamp has the ability to drop down an additional 4 inches and is secured by a pin with a diameter of approximately 0.250 in. This hole causes a stress concentration which was calculated to be $K_f = 2.55$. This concentration drops the ultimate strength of the $\frac{1}{8}$th inch thick aluminum from 10,000 psi to around 4,000 psi, however once the normal stress is calculated it is clear to see that this factor is not even an issue; the stress is only 2.32 psi. The result of this design, using two pieces of strong square tubing made of lightweight aluminum joined by extremely strong welds, is a clamping mechanism that is portable, lightweight, and capable.

![Figure 5: Side and Top Views of Clamp and Tube](image)

2. **Base**

As stated, the base (Figure 6) serves two very important functions in the device. First off, the base is the foundation of the easel, and without a strong and stable foundation the device would be a complete failure. To achieve this strong and stable base, two-inch square aluminum tubing will be used and the base will basically form the shape of a square with two protrusions on the front to facilitate the clamping mechanism. The second function of the base is movement. A linear actuator is attached to the rear of the base and extends to the carriage, which rides on a heavy duty I-beam door track.
capable of handling a tensile force of 300lb (http://jhus.com/2000.asp) that is attached back to the base. This setup allows for a total movement of 6 inches of motion front and back, extending a maximum of 4 inches from the front of the base and retracting to a minimum of 2 inches behind the front of the base.

As can be seen in the “Static Analysis of Base,” the base is subjected to rather small stresses as well. Without the carriage which weighs approximately 15 lb, the weight of the base alone, a surprisingly small 7.84 lb, is subjected to a stress of only 0.0426 psi and a negligibly small moment created by the combined weight of the two clamps which is easily counteracted by the weight of the base and the center of gravity pushed to the rear of the base. When the weight of the carriage is added in to the weight of the base, approximately 23 lb, the stress exerted is increased to 0.124 psi and when the device is fully extended a moment of 210 lb-in is generated. The only real challenge for the structural integrity of the base comes when the device is misused and it is either hung off of or somehow sat on. When a 300lb person, the carriage, base, and clamps are added to a fully extended device a moment is generated equaling 5400lb-in, translating to a bending stress of 4050 psi, well within the ultimate stress of 10,000 psi and giving a factor of safety of $N = 2.5$.

Figure 6: Top-Down View of Base and Front View of Tubing
3. Carriage

An important feature to consider was the collapsing capabilities our project requires, allowing storage of the easel to be simple and space efficient. By allowing a quick retraction of the tilting actuator, the easel collapses in the following way:

**Figure 7:** Collapsing Abilities

![Collapsing Abilities](image)

Movement of the carriage is defined by the angle the actuator makes with the base. This angle \( \theta \) is defined to have an angular acceleration:

\[
a \equiv (r' - r \theta'^2) \ddot{\theta} + (r \theta'' + 2r \theta') \dot{\theta}
\]

It depends on the velocity of the radius of curvature and change in \( \theta \) as a function of time. In order to evaluate the carriage components, including the bearing force on pins at A and B, we will work backwards from the easel face, working downwards.

The mass of the easel face is simply the addition of the five flat-stock aluminum pieces situated around the front plate. Using the density of aluminum, \( \rho = .095 \text{ lbs/in}^3 \), the mass of the easel face is found by calculating the volume of each part:

- \( V_a = 1.0 \text{ in} \times .25 \text{ in} \times 17 = 4.25 \text{ in}^3 \times .095 = .404 \text{ lbs} \)
- \( V_b = 1 \text{ in} \times .25 \text{ in} \times 18 = 4.5 \text{ in}^3 \times .095 = .4275 \text{ lbs} \)
- \( V_c = 1 \text{ in} \times .25 \text{ in} \times 6 = 1.5 \text{ in}^3 \times .095 = .1425 \text{ lbs} \times 2 \)
- \( V_d = .5 \text{ in} \times .25 \text{ in} \times 18 \text{ in} = 2.25 \text{ in}^3 \times .095 = .214 \text{ lbs} \)

Adding these values together yields a total mass for the easel face of 1.33 lbs located 3.5 inches from the screw drive. This weight is exerted down, off the end of the bracket. The brackets mass and cross bar center of gravity can be found similarly:

- Horizontal plates= \( .25 \text{ in} \times 3 \text{ in} \times 4 \text{ in} = 3 \text{ in}^3 \times .095 = .285 \text{ lbs} \) located 1.5 inches from the screw drive
- Vertical Plate= \( .25 \text{ in} \times 2 \text{ in} \times 4 \text{ in} = 2 \text{ in}^3 \times .095 = .19 \text{ lbs} \) located 3.125 inches from the screw drive.
Cross Bar = .25 in x .5 in x 10 in = 1.25 in x .095 = .119 lbs located 2.33 inches from the screw drive.

An important consideration is the weight of the canvas. Although the size of the canvas was mentioned in the dimensions section, the weight of the canvas has not been quantified. We will assume a maximum canvas weight of 10 lbs located 3.5 inches from the screw drive.

Summing moments about the screw drive yields:

\[ \Sigma M = 1.33lzs \times 3.5in + 10lbs \times 3.5in + .285lbs (2) \times 1.5in + .19lbs \times 3.125 + .119lbs \times .233in \]

\[ = 41.13lb \times in \]

The screw drive under consideration is the Kerk ScrewRail Actuator whose coaxial design saves as much as 80% of the space used by a two-rail system and is generally less expensive than the equivalent components purchased separately. The savings can be substantial due to lower component costs and reduced labor. (http://www.kerkmotion.com/products/slides-actuators/screwrail-act-overview.asp)

**Figure 8:** Static Analysis of Easel Face and Bracket
For vertical motion, it is important that the easel will not be limited by other movements. The weight the actuator must hold in the vertical position includes the weight of the canvas, easel face structure (found above), and the rectangular tubing. This value is 14.55 lbs, very light considering the weight limits of the actuator. The vertical displacement will be 6” and will allow for movement at different tilting angles. A figure showing how the vertical movement is achieved is seen on the next page.

**Figure 9:** Vertical movement

The tilting function is adjustable for angles of 10 degrees back and 40 degrees forward from the vertical position. At these angles, limit switches will be adjusted in order to protect against the easel hitting against the lower arms of the base. In the full forward position, the easel can tilt to its maximum while achieving its lowest vertical limit. This is seen as extending Line A in figure 10.
Next, the pins attaching the vertical uprights about which the easel will tilt will contain shear and bearing stress from the weight of the carriage. Bearing stress is defined as: \[ \tau = \frac{F_{\text{pin}}}{td} \] Using a pin of diameter .25 inches, and thickness of the vertical columns as .5 inches, we can calculate the bearing stress once the force exerted down by the pin is estimated. Each vertical column has masses of .1.436 lbs. We shall consider the horizontal screw rail and vertical actuator to weigh 2 pounds each. The canvas frame, bracket, and horizontal shaft were found to be 14.55 lbs (assuming 10 lb. canvas). The two glide bars have a total weight of 1.26 lbs and the angle cross pieces have combined masses of 1.5675 lbs. Finally, the channel piece protecting the vertical actuator has a mass of .82 lbs. Combining this weight gives a total downward force of 21.069 lbs acting down on the pins. Dividing this weight into two pins results in an accurate estimation. The bearing stress of the pin is thus:

\[ \tau = \frac{10.53}{.25 \times .5} = 84.24 \text{ lbs/in}^2. \]

Stainless steel pins will easily maintain this load.

Electrical System

The electrical system controlling the easel is a vital component in the overall functioning of the system. While it requires little mechanical design, the mechanism
controlling current flow throughout the system must be efficient, practical, and reliable as it powers the actuators which are perhaps the most important modules in the design.

The easel itself will be powered by 120 VAC which will be supplied from a standard wall socket. On the back of the easel will be a male, 3-prong 120VAC plug. This will allow the user to power the easel via an extension cord of any desired length. This also prevents any excess of wire from having to be attached to the easel and allows for the cord to be removed whenever desired. The ground terminal of from the socket will be attached to the aluminum frame of the easel to protect against any electrical shocks in the event of an accident or malfunction. The 120V line from the socket will feed into a single pole single throw switch which will be mounted to the frame and serve as a master control for the easel. Dependent on the needs of the user, this switch may be a single on/off switch or a combination of a keyed switch along with an on/off switch. Essentially, if a keyed switch it used, it will be connected in series with a separate on/off switch. This will allow the power to be first turned either on or off using a key to prevent undesired operation of the easel. Then, once the key switch is enabled, the master switch can power the easel. By turning the switch off, all current flow to the easel and its circuit is halted.

The output leg of the switch and the neutral line of the socket will then be split to two places. First, it will run to a female, 3-prong 120VAC receptacle which will be mounted to the back of the easel. This essentially functions as an additional plug on the easel that can be used for any accessories that might be added. The most likely use of this plug would be to power a light which attaches to the easel for purposes of lighting the canvas. After attaching to the outlet, the power feed will then run to the control circuit for the easel movement.

Movement of the easel will be controlled by four separate linear actuators; one to control each possible direction of movement. The actuators used in the system will run on 12 volts DC and at a full load will draw 3 amps. To account for this, the 120VAC supply voltage will need to be stepped to 12 volts DC. Because a maximum of two actuators can be run at any time the total current draw for the circuit should not exceed 6 amps. To convert the voltage a transformer will need to be used to step down the voltage and a rectifier to convert it to DC. To protect against any current overload, a fuse will be inserted into the +12 VDC leg from the transformer. Any circuit portion drawing more than 6 amps at any given time would indicate a malfunction with the unit. The +12VDC and ground legs from the transformer will then run to a number of locations. Eight relays will be used to control the current to the actuators. These relays will be double pole double throw and rated for 5 amps at 12V. The main terminal of each of the two poles will be connected to +12VDC and ground respectively. The normally closed terminals will be left unwired, and the normally open terminals will be wired to the two legs of the actuator. Two relays are needed for each actuator; one to control extension and a second retraction. This is because the direction of the actuator is controlled by simply reversing the polarity of the voltage. Therefore each set of 2 relays will be wired oppositely.

Two joysticks will used to control the movement of the easel and will consist of a 4 directional handle and 4 separate momentary micro switches – one switch for each direction. Currently, the joysticks that are planned for use in the easel are Universal Microswitch Joysticks manufactured by Happ Controls. Because the switches are not capable of carrying the high 3 amp load of the actuators, each switch will be connected to
a +12 VDC supply. The output of each switch will be wired to one end of the coil on one of the relays. The second end of the relay coils will be connected in parallel to ground. As a result, when one of the joysticks is moved in a certain direction, the micro switch will be activated. This will allow the 12VDC to power the coil in a particular relay. The relay mechanism will then engage the contacts on its poles and allow the actuator to be powered.

Since each joystick will have a total of five wires which will carry minimal current to trip the relays, it will be convenient to use RJ-11 (telephone) cable for the connections as this is well suited for the application and makes connecting or disconnecting the joysticks a simple process.

This design allows for more than one actuator to be active at a time by using the two joysticks. However, because of the mechanics of the joystick, only one direction of any actuator can ever be active at a time. A full circuit diagram can be found in Figure 11.
Optimal Design Budget

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Timeline:
A timeline for the project can be found attached to this report.

Conclusion:
Designing the most efficient electrically adjustable easel is a task that involves intricate evaluation of mechanical, material, and electrical principles of a device. After gathering a variety of information and doing a surplus of research, a well developed plan as to the fabrication and achievement of the easel has been derived. Specified dimensions, movements and safety features have all been incorporated and integrated within this design.
References

**CMC Technical Support and Service Department:**
7550 Hub Parkway
Cleveland, OH 44125 USA
(800) 321-8072 : Toll Free
(216) 642-5164 : Direct Dial
(216) 766-8480 : After Hours
(216) 642-5159 : Fax

9” actuator

Drawer Tracks
http://www.udb.cc/ProductType.aspx?product_type_id=113

Screw Drives
Joysticks
http://www.happcontrols.com/joysticks/joysticks_amusement.htm
Static Analysis of Clamp Under Own Weight - Aluminum

\[ \rho_{Al} = 0.095 \text{ lb/in}^3 \]
\[ V_1 = (4)(1)(1) - (4)(0.75)(0.75) = 1.75 \text{ in}^3 \]
\[ V_2 = (17)(1)(1) - (17)(0.75)(0.75) = 7.44 \text{ in}^3 \]
\[ V = V_1 + V_2 = 9.19 \text{ in}^3 \]
\[ W = V \rho_{Al} = (9.19)(0.095) = 0.87 \text{ lb} \]
\[ Cc = (5, 1.25) \]
\[ \sum F_y = 0 = F_A - W \quad \sum F_x = 0 \]
\[ F_A = 0.87 \text{ lb} \]
\[ \sum M_A = 0 = -(0.87)(4.5) + M_A \]
\[ M_A = 3.92 \text{ lb-in} \]

**FBD 1**
\[ \frac{D}{d} = \frac{1}{0.75} = 1.33 \]
\[ \frac{r}{d} = \frac{0.125}{0.75} = 0.17 \]
\[ S_U = 10,000 \text{ psi} \]
\[ \sigma_{MAX} = \frac{10,000 \text{ psi}}{2.55} = 3921.57 \text{ psi} \]
\[ A = 0.1875 + 0.1875 = 0.375 \text{ in}^2 \]
\[ \sigma_w = 2.32 \text{ psi} \]
\[ N = \frac{3921.57}{2.32} = 1690.33 \]

**Pin Through Hole**
\[ \tau_{pin} = \frac{0.87 \text{ lb}}{2\pi(0.125)^2} = 8.86 \text{ psi} \]
Static Analysis of Base - Aluminum

\[ \rho_{Al} = 0.095 \text{ lb/in}^3 \]

\[ V_1 = V_4 = (2)(2)(22) - (1.75)(1.75)(22) = 20.63 \text{ in}^3 \]
\[ V_2 = (2)(2)(24) - (1.75)(1.75)(24) = 22.50 \text{ in}^3 \]
\[ V_3 = (2)(2)(20) - (1.75)(1.75)(20) = 18.75 \text{ in}^3 \]
\[ V_B = 2V_1 + V_2 + V_3 = 82.51 \text{ in}^3 \]
\[ W = \rho_{Al}V_B = (0.095)(82.51) = 7.84 \text{ lb} \]

**Stress Exerted on Table (Own Weight)**

\[ A = (2)(2)(24) + (2)(20) + (2)(24) = 184 \text{ in}^2 \]
\[ \sigma = \frac{7.84 \text{ lb}}{184 \text{ in}^2} = 0.0426 \text{ psi} \]

**Approx. Stress Exerted on Table (Base + Carriage)**

\[ A = 184 \text{ in}^2 \]
\[ \sigma = \frac{7.84 + 15}{184} = 0.124 \text{ psi} \]

**Approx. Moment Exerted on Center of Mass of Base by Fully Extended Drawing Surface**

\[ Cc_x = 10 \]
\[ \sum M_{Cc_x} = -M_{Cc_x} + (15)(14) = 0 \]
\[ M_{Cc_x} = 210 \text{ lb - in} \]

**Approx. Moment Exerted on Center of Mass of Base by Misue (Hanging off by 300lb User)**

\[ Cc_x = 10 \]
\[ \sum M_{Cc_x} = -M_{Cc_x} + (300)(18) = 0 \]
\[ M_{Cc_x} = 5400 \text{ lb - in} \]
\[ \sigma_B = \frac{Mc}{I} = \frac{(5400)(1)}{\frac{4}{12}2^4} = 4050 \text{ psi} \]