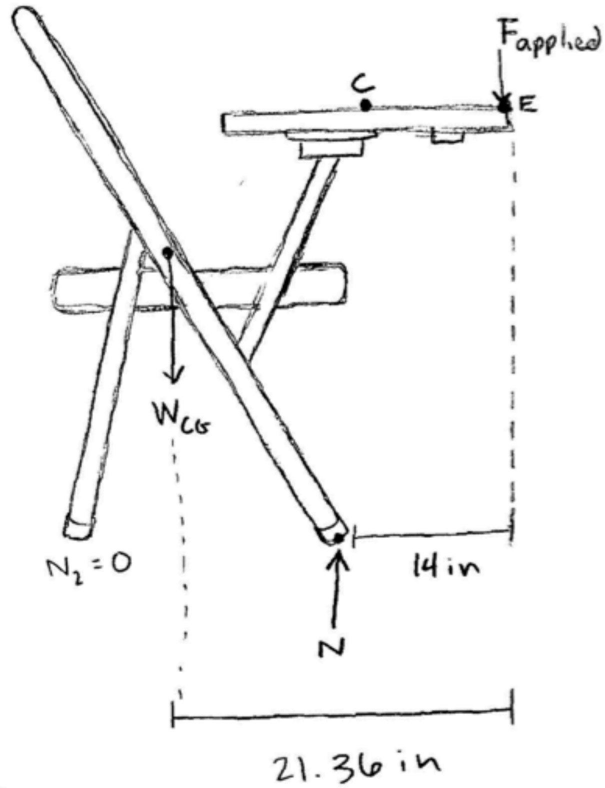
Analysis Design Review 2

In order to address the client's concerns and questions certain sets of mechanical analyses were performed on the folding chair design model. A drawn model of the folding desk is given below:



As can be seen on the diagram, point C represents the absolute center from any edge on the tabletop. The first task was to find the maximum force that could be applied to the edge of the table (point E) and the maximum force that could be applied to the center (point C) without the entire system tipping. This calculation was made with the assumption that nobody would be sitting in the chair at this point in time. When someone is sitting in the chair, it will not tip for the purposes of this product. This assumption is based on the fact that the weight of the user will counter the to whatever force is placed on the desktop. When a user is not present, the limits to how much downwards force that can be applied to tabletop before tipping was deemed to be a important calculation to make.

In order to complete this task a free body diagram needed to be created. The figure above serves as the free body diagram. For notational clarity $F_{applied}$ is the applied force at point E, the end of the table. The downwards arrow represents the force vector as the force will be applied vertically downwards. This is the force we are solving for. Note in the case for finding the maximum force ($F_{applied}$) at point C, the force vector will be pointing downwards at point C. The upwards force vector N at point N represents the normal force of the ground acting on the chair. W_{cg} represents the downwards force of gravity acting on the chair. This force is equal to the weight of the chair. Although the diagram shows that this force acts 21.36 inches from point E in the x-direction, this distance needed to be calculated. This calculation is explained below.

Determining the center of mass in the horizontal direction (the distance of the force vector, W_{cg} from point E) proved to be necessary for later calculation. The formula for the x center of mass of any object is given below:

$$x_{cm} = \frac{\sum_{i=1}^{n} m_i x_i}{\sum_{i=1}^{n} m_i}$$

Note x_{cm} is the x center of mass (the quantity we are trying to determine), m_i represents every individual mass element present in the object, x_i is the distance of each individual mass element from the chosen '0' point. In the case of our calculation we chose the 0 point to be point E. This way, the x_{cm} we calculate will be the distance of the center of mass of the chair (where W_{cg} acts) from point E. For our center of mass calculation we divided the table into 6 separate subassemblies, which we knew the mass of. A detailed list of each subassembly is given in the Appendix including illustrations and mass values. The team broke the system into subassemblies because the masses were known and individual center of gravities of these pieces could be determined by symmetry rather than calculated in an equation. The modified equation we used for this calculation is given below:

$$x_{cm} = \frac{m_1 x_1 + m_2 x_2 + m_3 x_3 + m_4 x_4 + m_5 x_5 + m_6 x_6}{m_1 + m_2 + m_3 + m_4 + m_5 + m_6}$$

Note that m_1, m_2, etc. refer to the mass of each subassembly (details in Appendix) and x_1 , x_2, etc refer to the distance of each subassembly from point E in the horizontal direction. Note that each numbered subscript refers to the same number subscript of each subassembly in the Appendix. The Appendix gives an illustration of each subassembly, the mass value (m) and the distance (x) from point E in the horizontal direction. It was found that the center of mass was determined to be 21.36 inches from point E. This physical representation can be seen in the diagram.

As stated before, the location of the center of mass is also where the W_{cg} force acts downwards on the chair assembly. This location was important in order to determine the maximum forces that could be applied at the specified points on the table without it tipping. This will be shown in the following calculation.

To finally calculate the maximum forces that we desire, a moment balance was performed on the system. A couple assumptions were made beforehand in order to make this calculation. The first assumption is that the system can be modeled in 2 dimensions as seen in the figure previously shown. Normally this assumption would not be valid because the chair is not perfectly symmetrical (there is only a one arm support of the table). This assumption is valid in this case because of the way the chair table assembly is constructed. The table and arm assembly is a separate rod that runs through the entire bottom of the chair (underneath the seat) so the table will not tip about the horizontal axis in the given figure above. The second assumption made for this calculation is that the normal force from the ground to the chair at point N_2 will be equal to 0 at tipping. This is because right when the chair begins to tip, the back legs (at point N_2) will no longer be touching the ground. Hence, there will be no force from the ground on the chair at this point.

Now that the assumptions have been stated, the calculation for the maximum force loads was made using a simple moment balance equation. This equation is given below:

$$\Sigma M_N = 0$$

Because the system is still a static system, it is not in motion. The sum of moments about any point in the system will equal to 0. For the purposes of this calculation the point chosen was point N. This point was chosen because the upwards force N is unknown and we already need to determine an unknown force $F_{applied}$. The moment equation is then applied as so:

$$\Sigma M_N = 0 = W_{cg} X_{cg,N} - F_{applied} X_{F_{applied},N}$$

Where W_{cg} is the weight of the assembly (17lbs), $X_{cg,N}$ is the distance from W_{cg} to N (this distance is known since x_{cm} has been calculated it equals 7.36 in), $F_{applied}$ is the maximum force applied at point E, and $X_{cg,N}$ is the distance from point E to point N (14in). Plugging in and solving yields the following value:

Maximum force at point E = 8.94lb

To find the maximum force at the center of the table (point C) the above equation is still used with the same values with one change; $X_{cg,N}$ is now the distance from point C to N. Plugging in and solving yields the following value:

Maximum force at point C = 17.87lb

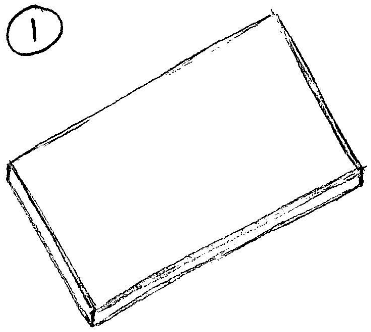
The weight of the desk chair was determined to be around 17 pounds from component selection and estimates in CAD software. When the desk chair is fully folded it stands completely vertical. It was then determined that because of this, the user needs to apply the necessary 17 pounds of force to lift and carry the desk chair.

The folding desk chair is similar in ease of use with regards to folding and unfolding with competitor folding chairs. It was then determined that the force required to fold and unfold the desk chair was the same was regular folding chairs. Though this force can vary from chair to chair, it stays at a relatively low value. It was determined that the folding desk chair needs very low forces to fold and unfold.

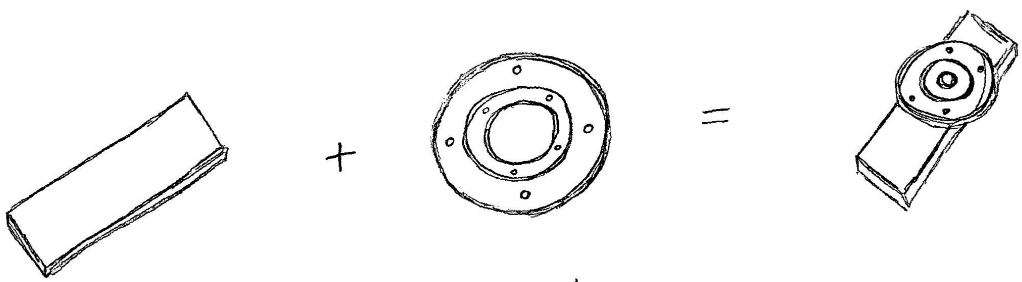
Appendix

ABLE SUBASSEMBLY → includes:

①

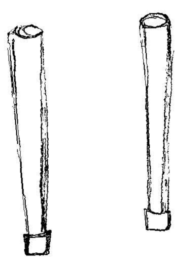


desk



desk support

turntable



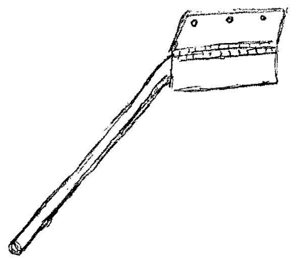
legs

total weight:

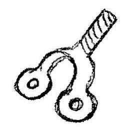
~ 4lb

SUPPORTING ARM SUBASSEMBLY → includes:

(2)



+



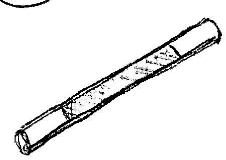
arm + hinge
(one component)

rod end

total weight: ~ 2 lb

SUPPORTING BAR SUBASSEMBLY → includes:

(3)



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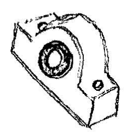

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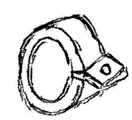
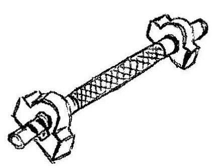


bar

bearings (2)

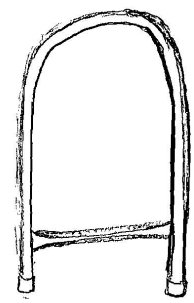
clamp

= 

total weight: ~ 3 lb

CHAIR BACK COMPONENT

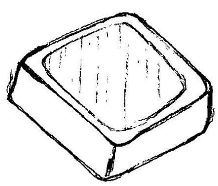
④



weight: ~3 lb

SEAT COMPONENT

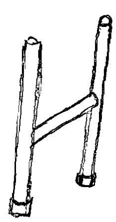
⑤



weight: ~3 lb

CHAIR LEGS COMPONENT

⑥



weight: ~2 lb

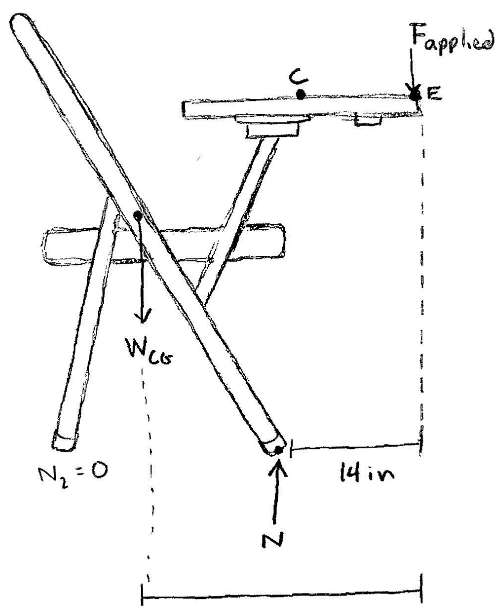
Chair unfolded without supporting legs (Note ①, ②, etc refer to the respective subassembly)

Center of mass (x axis): Note position is relative to edge of table

$$X_{cm} = \frac{m_{①} x_{①} + m_{②} x_{②} + m_{③} x_{③} + m_{④} x_{④} + m_{⑤} x_{⑤} + m_{⑥} x_{⑥}}{m_{①} + m_{②} + m_{③} + m_{④} + m_{⑤} + m_{⑥}}$$

$$= \frac{(4lb)(7in) + (2lb)(10in) + (3lb)(14in) + (3lb)(25in) + (3lb)(24in) + 2lb(31in)}{4lb + 2lb + 3lb + 3lb + 3lb + 2lb}$$

= 21.36 in from edge of table



(Fapplied at point E)

$\Sigma M_N = 0 = (W_{CG})(7.36in) - F_{applied}(14in)$ $W_{CG} = 17lb$

$F_{applied} = 8.94lb$ (max value before tipping)

If Fapplied is at point C

$\Sigma M_N = 0 = W_{CG}(7.36in) - F_{applied}(7in)$

$F_{applied} = 17.87lb$ (max value before tipping)