Sustainable Chair Design

Mateusz Rychtarczyk

***Abstract*— This report contains conceptual designs, analysis, and assembly of a sustainable chair that was built entirely of foam core board. This chair was designed to hold an $80kg$ person and follow strict design requirements. The stress analysis of the design and techniques used when designing the chair are presented. The successful experimental results are also shown.**

I. Introduction

For the first project in MMAE 232, I designed a sustainable chair made out of foam core board that held an $80kg$ person (see Fig. 1). The design had to follow specific size constraints, which included:

- Seat height between 480mm and 530mm
- Seat depth between 380mm and 420mm
- Seat width between 380mm and 420mm
- Backrest height between 250mm and 450mm

Other requirements included a weight restriction of $500g$, all pieces had to interlock (no use of fasteners,glue,etc.), and it had to be constructed from 18" x 24"' x 3/16" foam core board. While the weight limit added a challenge to the project, the final design was still successful in meeting the requirements and functions desired.

II. Concept Generation and Evaluation

When generating concepts for this design, I chose to use the minimum requirements for the dimensions. This was to reduce the unnecessary components that would only add to the weight of the chair. The fact that the pieces had to fit on an 18" by 24" sheet was also taken into consideration, otherwise it would be impossible to cut them to the proper size for that design.

One important factor considered when designing for the strength of the chair was that most of the load on the seat would be concentrated in the center of the seat and closer to the backrest. This is because the person sitting in the chair would rest their back on the back rest, which also would create another force concentration on the center of the backrest.

This Pugh Chart (see Table 1) shows the evaluations of the three concepts that were designed. The baseline is 0, and the highest and lowest possible scores are +2 and -2 respectively.

III. Analysis

One major adjustment that was made to decrease the mass was the removal of the inner and outer support walls from the design. These added significant weight to the chair and were unnecessary as the chair could meet the functional requirements without the extra support from these walls. The lines of force through the support legs and backrest were considered when implementing light weighting techniques

Fig. 1. Final assembled chair.

TABLE I
Pugh Chart

	Baseline	**Design 1** (Fig. 2)	**Design 2** (Fig. 3)	**Design 3** (Fig. 4)
Strength	0	+2	-1	+2
Weight	0	0	+1	-2
Aesthetics	0	+1	+1	0
Assembly	0	+1	0	-1
Total	N/A	+4	+1	-1

(see Fig. 4). The three legs were filleted inward to reduce the unnecessary weight as well as the backrest supports.

After these adjustments to the design, the experimental mass was $479g$. This was calculated by multiplying the volume of the chair design by the average density of foam core board, $0.136g/cm^3$. The volume was found in the properties of the Inventor part file.

To analyze where potential stress concentrations would be located in the chair when under load, a stress analysis was performed in Autodesk Inventor using pressures applied to the seat and backrest. The pressure on the seat was increased until the major stress concentrations were made clearly visible. The same was done for the backrest. The applied

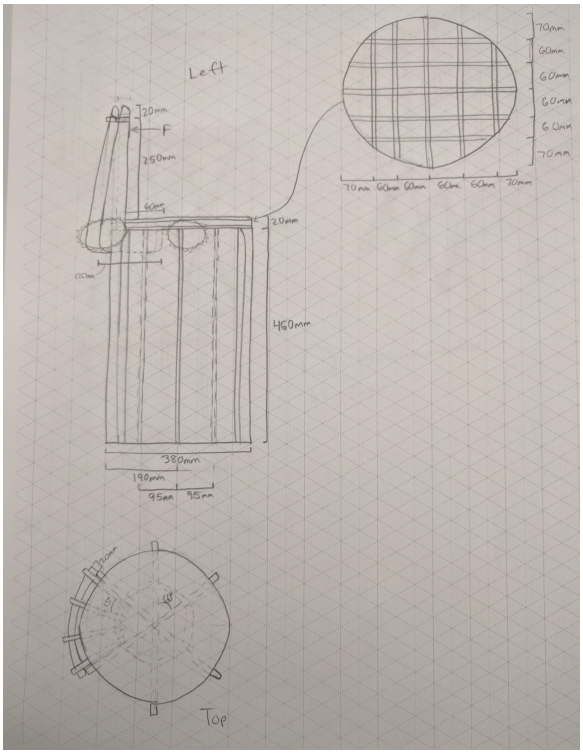


Fig. 2. Design 1.

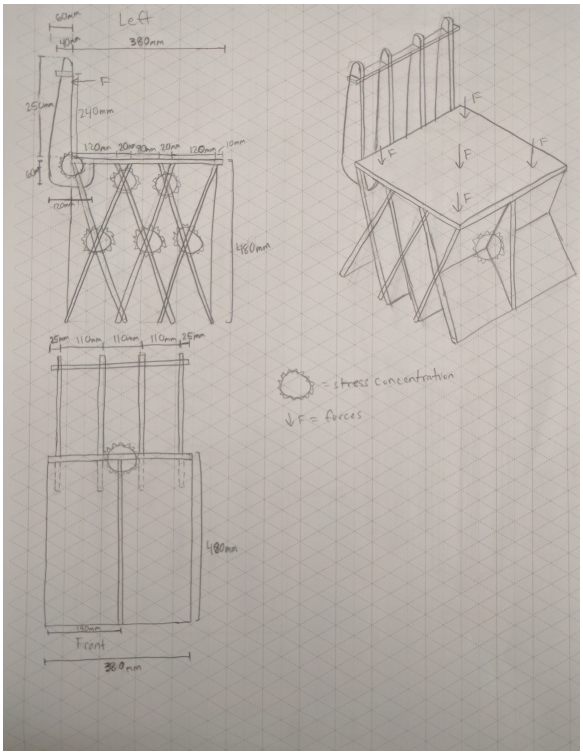


Fig. 3. Design 2.

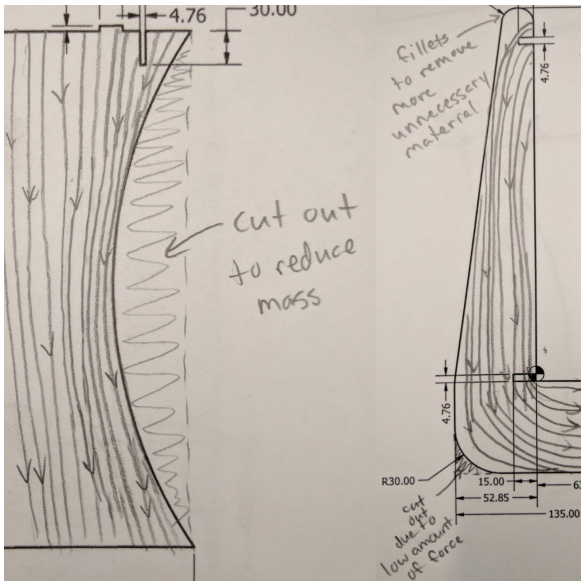


Fig. 4. Lines of force going through the support legs and backrest.

loads were intentionally higher than the chair would actually experience during testing to make the stress concentrations more visible, so all concentrations could be minimized.

The results of the stress analysis can be seen in Fig. 6, where the stress concentrations are indicated by the bright colored areas. The only major stress concentrations were found on the backrest joints connecting to the seat and a small part of the seat. Since these concentrations were relatively small in size and stress, even with the overestimated pressures, it was concluded a prototype was ready to be built and tested.

IV. Experimental Results

The final assembled chair is shown in Fig. 1. The actual mass of the chair was $504g$ when assembled, which was $25g$ heavier than the experimental mass. This was due to the varying density of the foam core board. To accommodate for this, holes were cut in the top of the seat where there was little load carried. This brought the mass down to $499g$, which was within the weight requirement.

The chair was first tested by myself even though I weighed about $85kg$. It held up very well with no bends in any of the pieces. The chair was then tested again by Prof. Spenko for a duration of about 20 seconds, in which he leaned back on the backrest and it flexed, but did not break or bend anywhere.

V. Discussion

One of the major light-weighting techniques used in this design was the use of fillets. The seat itself was circular, which helps reduce weight because it would still follow the size requirements, but removed the unnecessary corners of the seat. These corners would also most likely have high stress concentrations and would need extra support, thus adding weight. The legs of the chair also had large fillets taken out of the sides to remove excess material while maintaining low stress concentrations and high strength. The

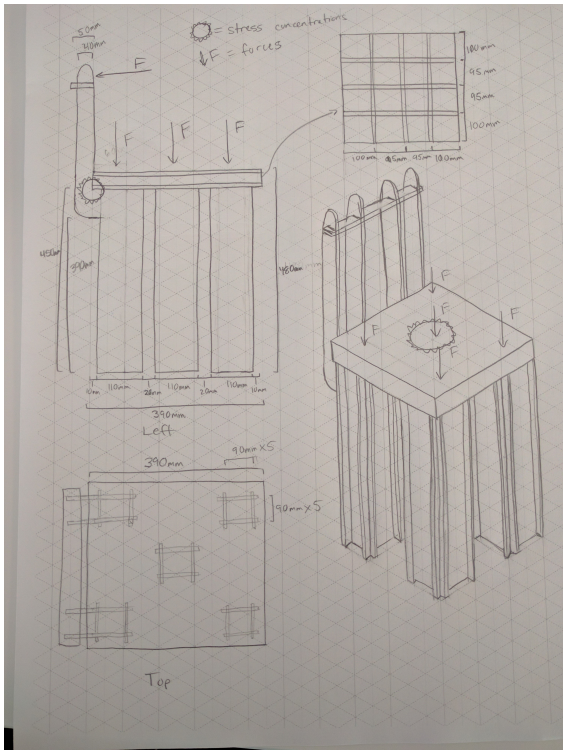


Fig. 5. Design 3.

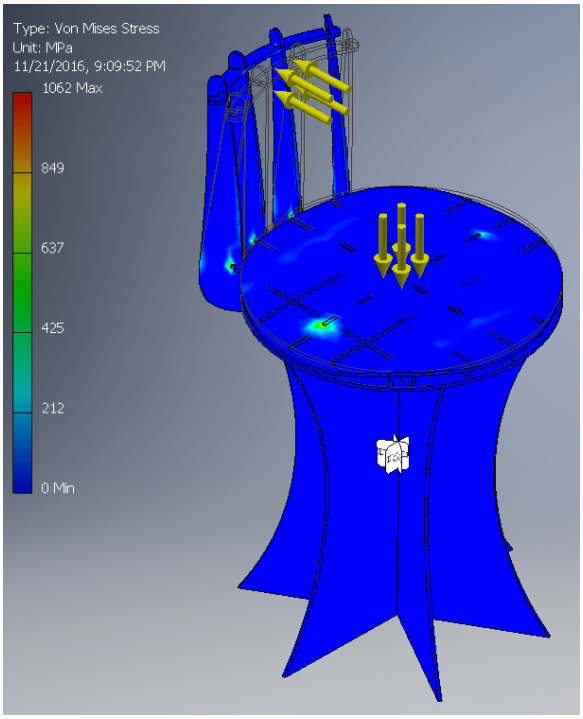


Fig. 6. Stress Analysis performed on the chair design in Autodesk Inventor.

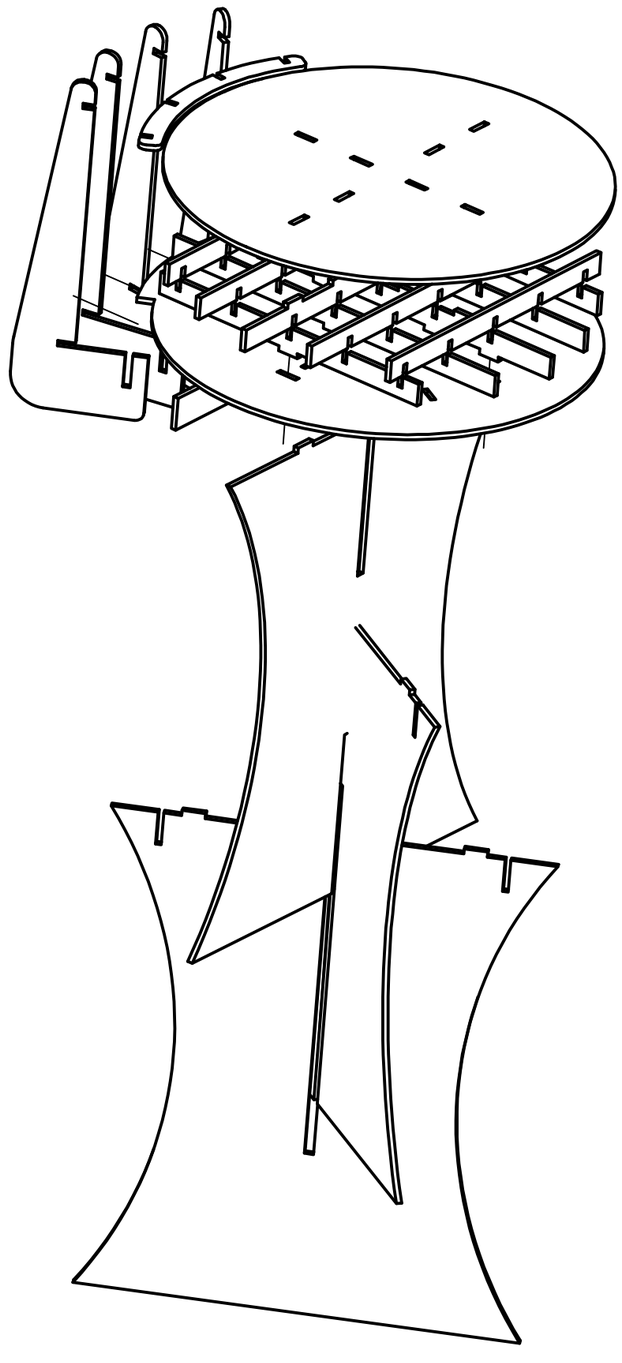
final use of fillets was in the backrest, purely for reducing weight as the corners were unnecessary. As stated in the experimental analysis, the holes in the seat were also cut out to reduce the weight to the requirement.

Another light weighting technique used was the ribs used in the backrest. A solid backrest would have added significant weight to the design, so the ribs were used. These were oriented perpendicular to the back of the occupant because the foam core board hold loads much better when they are applied in that direction rather than to the face of the board.

VI. Conclusions

Although this project seemed difficult at first, my chair design was successful in meeting the functional requirements. The design process started with 3 conceptual designs and choosing the design with the best outlook for success. The strength analysis of the final design was done after that to find major stress concentrations and eliminate them along with light-weighting to meet the weight requirement. The assembled version of the chair was too heavy, so some further light-weighting was needed. The final tests were successful with no failure observed in the chair.

This report was written in LaTeX.



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2	1	Main Support 2	
3	1	Seat Base Bottom	
4	2	Outer Seat Grid	
5	1	Center Seat Grid	
6	2	Seat Grid 1	
7	2	Seat Grid 2	
8	2	Outer Seat Grid 2	
9	1	Center Seat Grid 2	
10	1	Center Seat Top	
11	4	Backrest Support	
12	1	Backrest Upper Joint	
13	1	Backrest Lower Joint	

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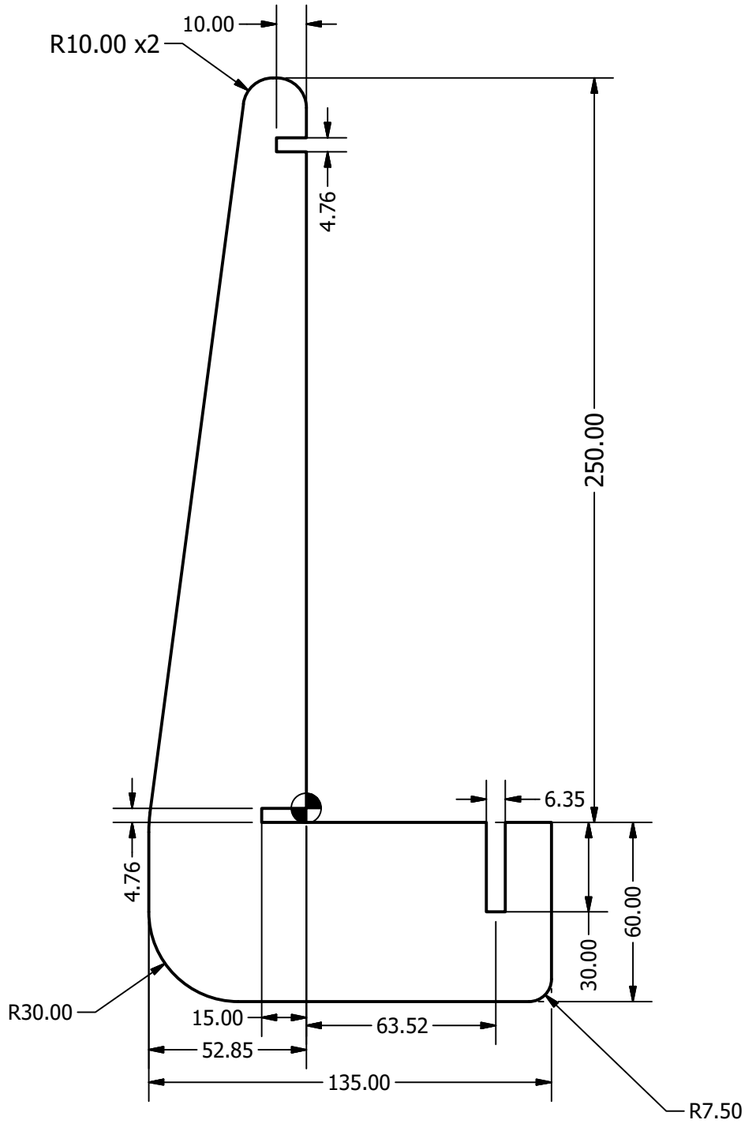

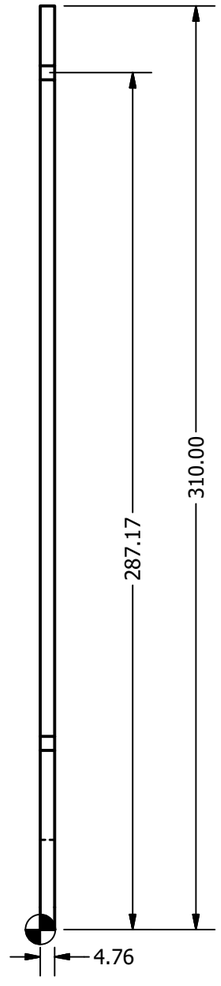

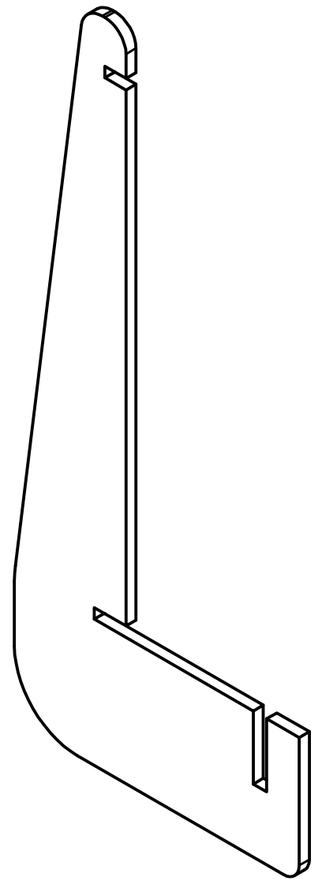

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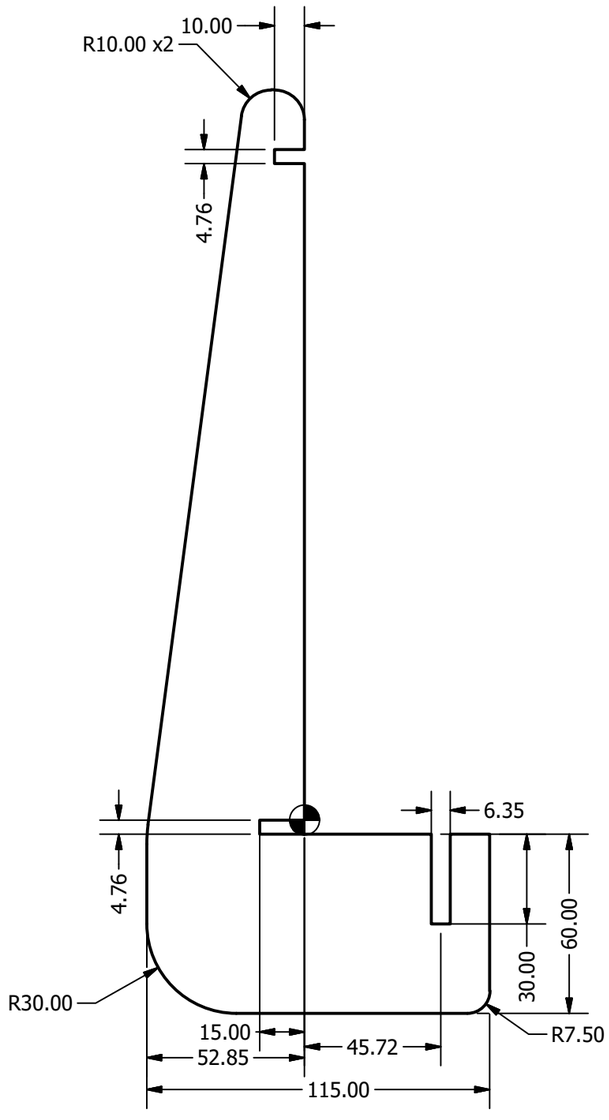

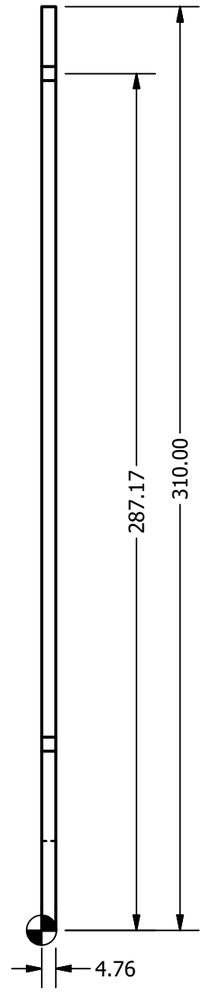

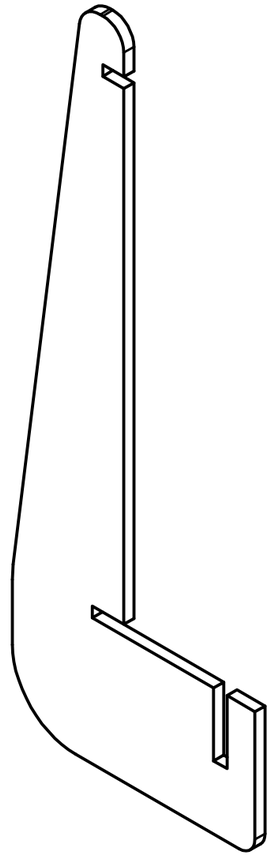

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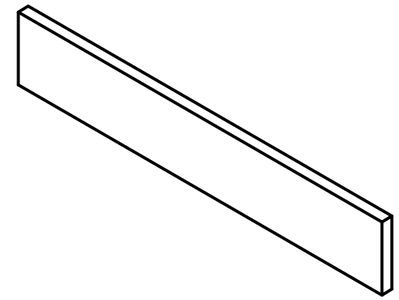

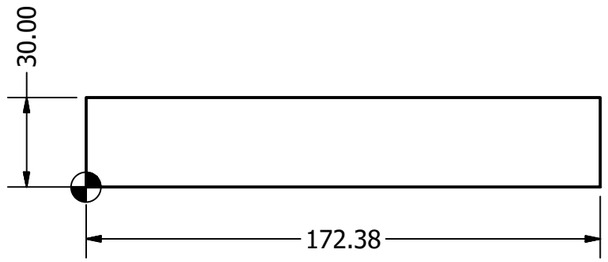

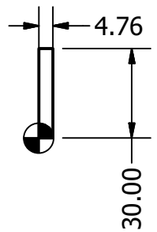

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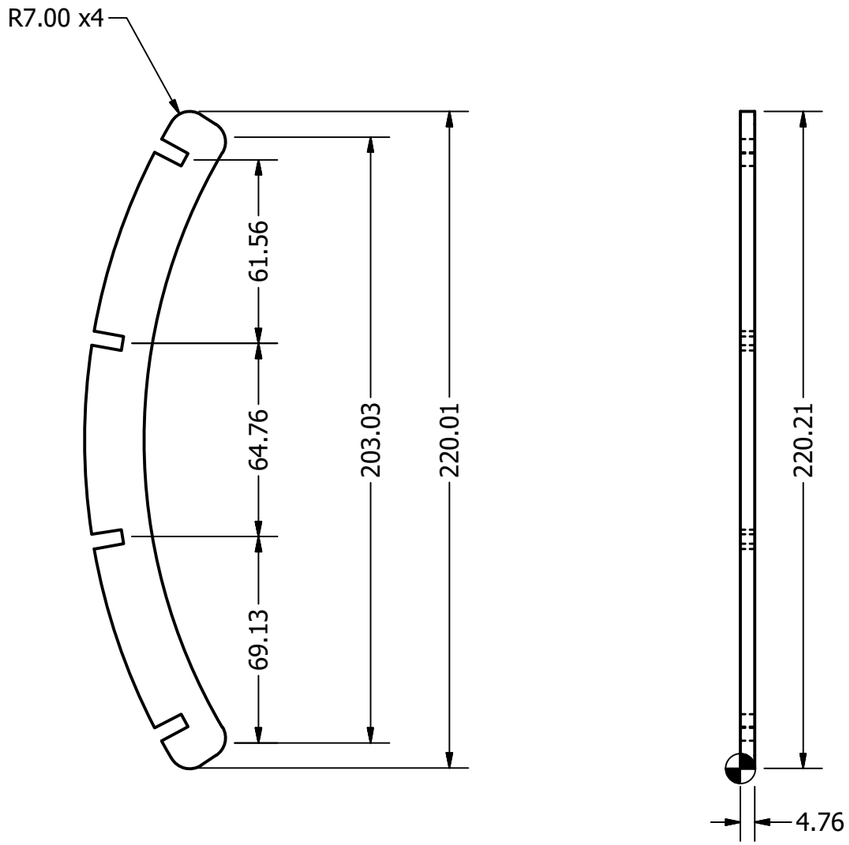

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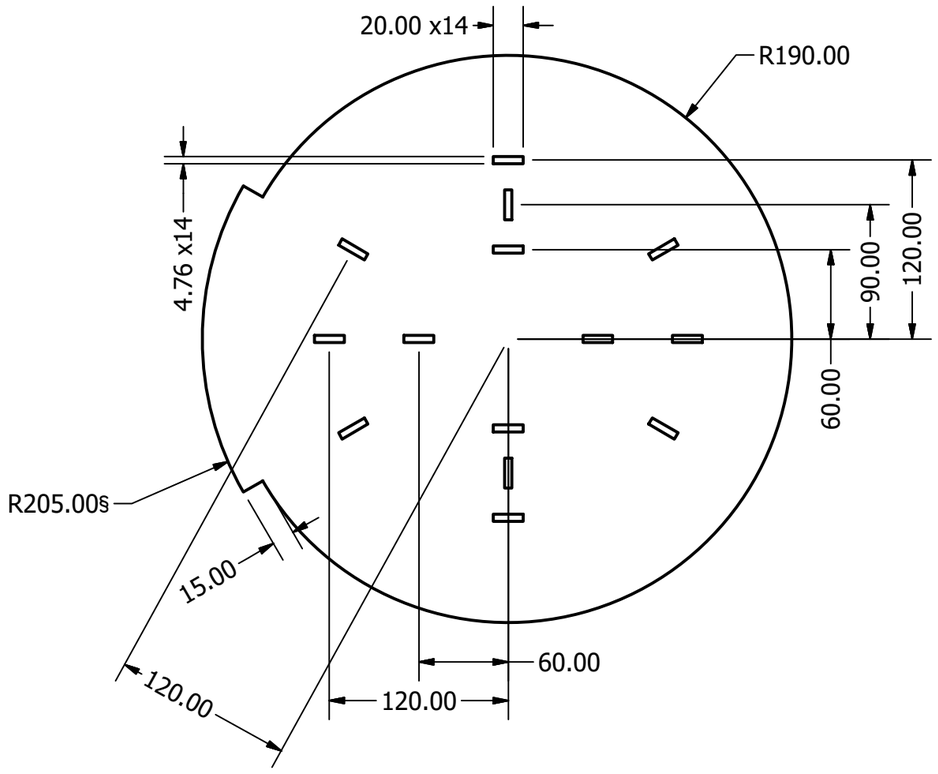
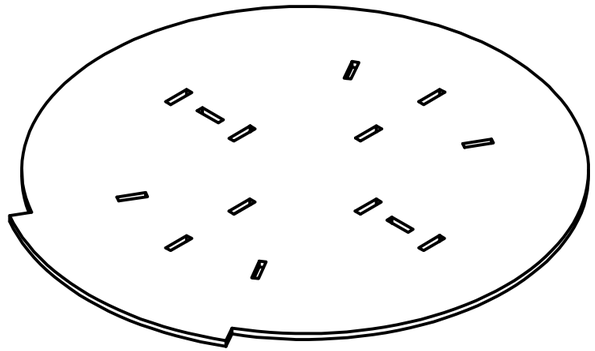
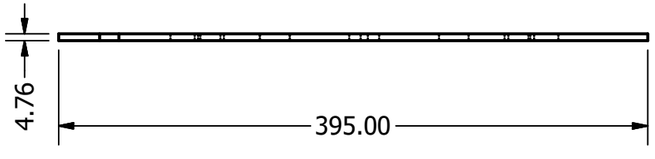
All cutouts are symmetrical







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Sustainable Chair Project

SIZE		DWG NO	REV
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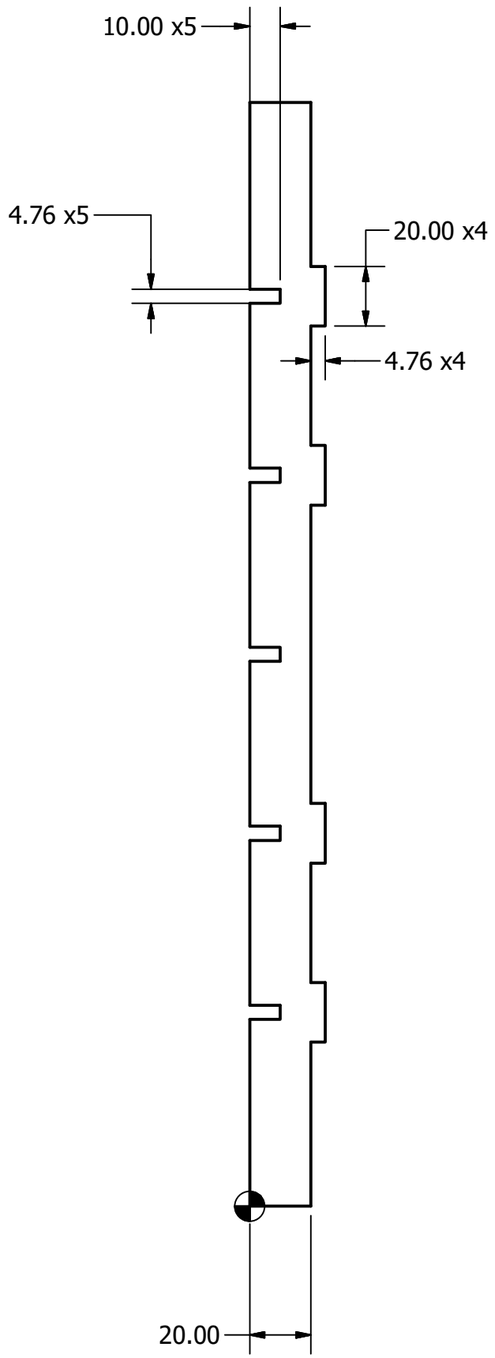
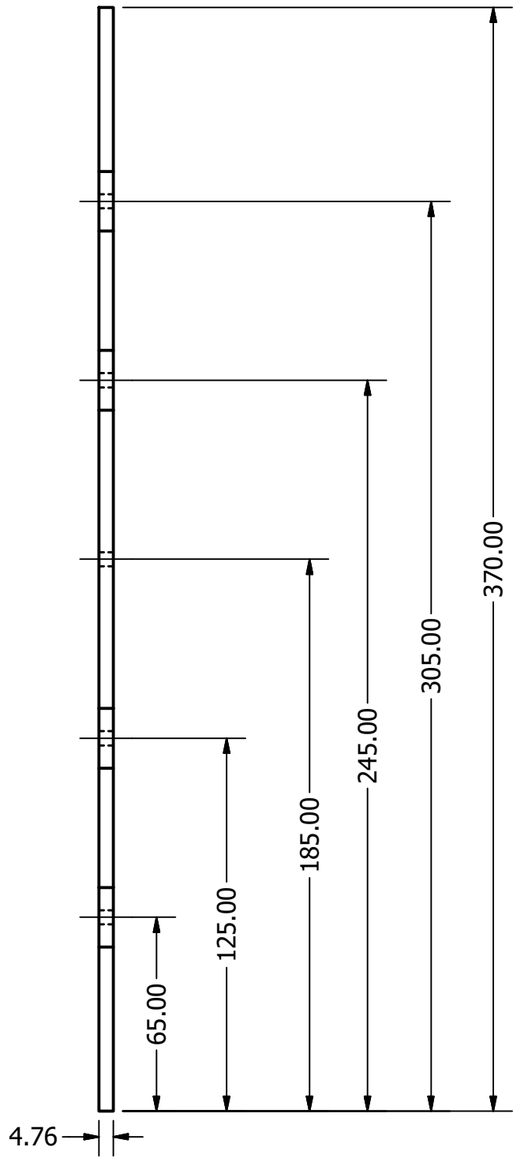
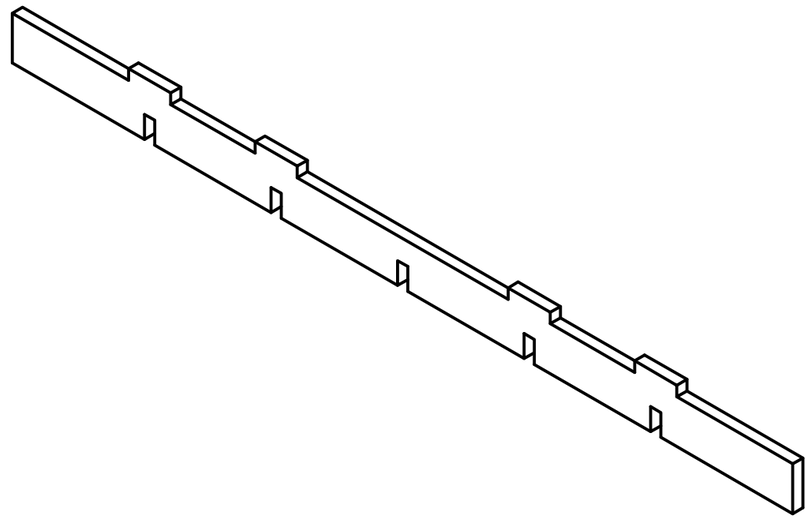
SCALE 1 / 4		SHEET 1 OF 1	







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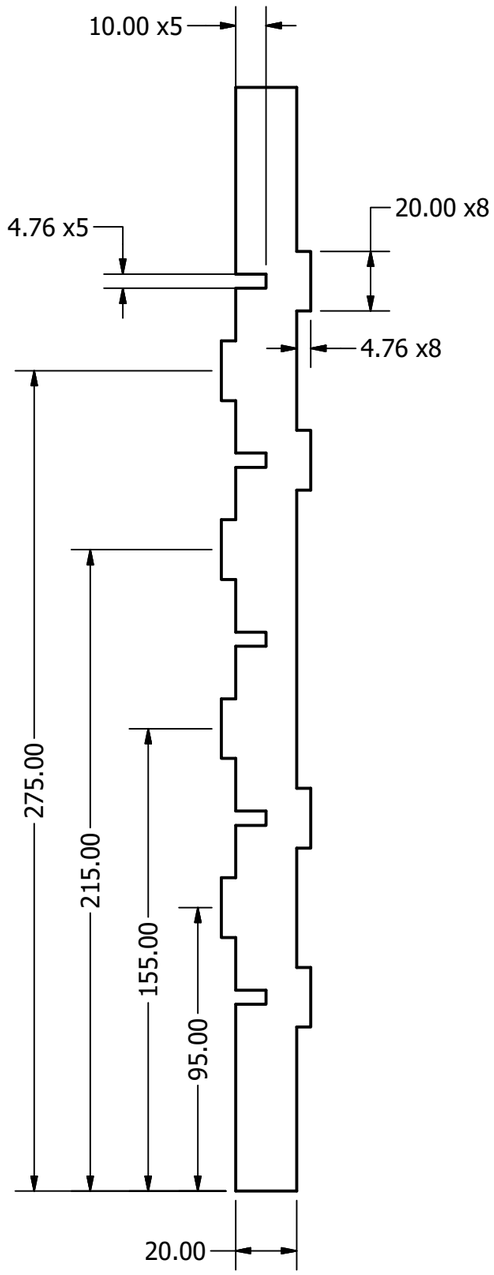

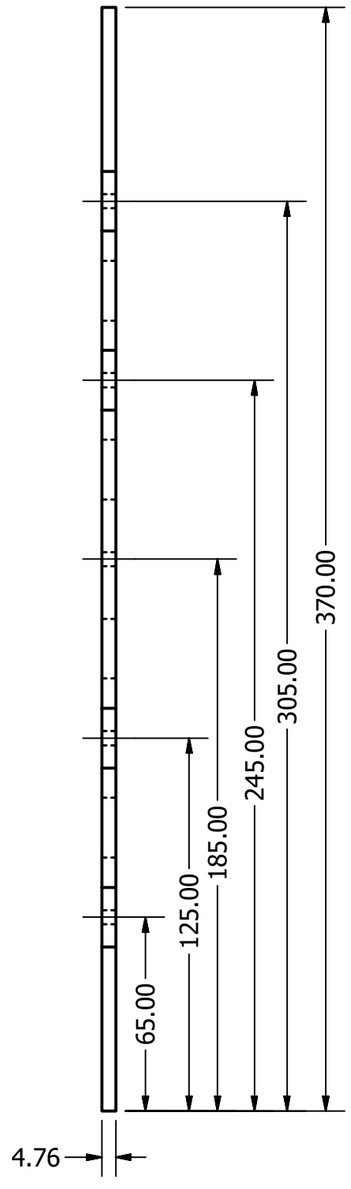

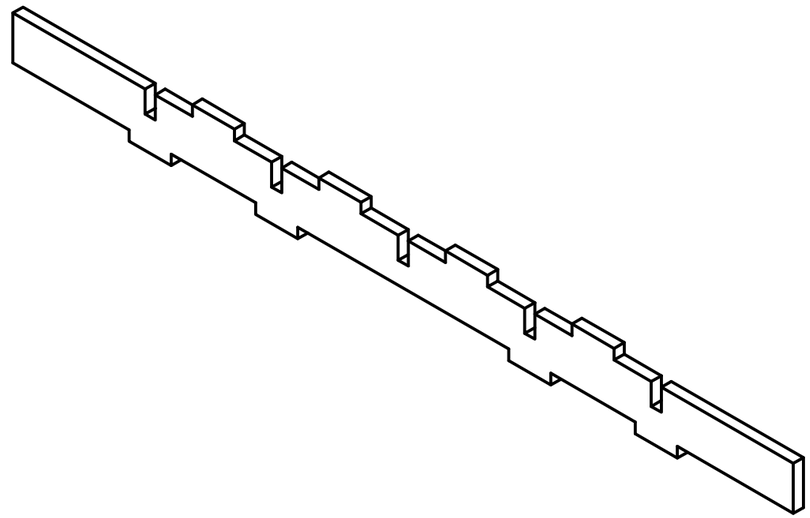

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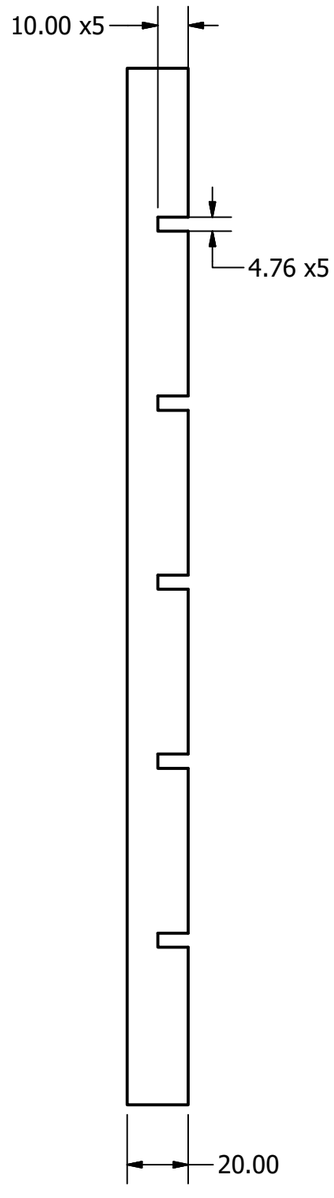

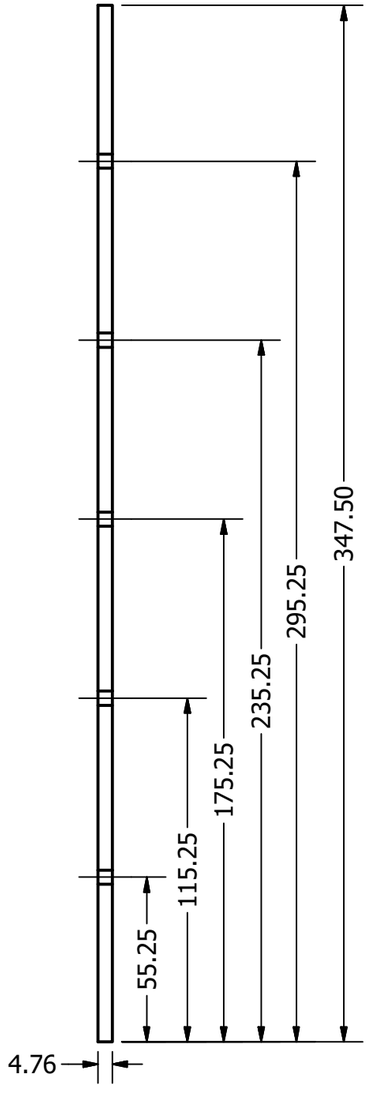

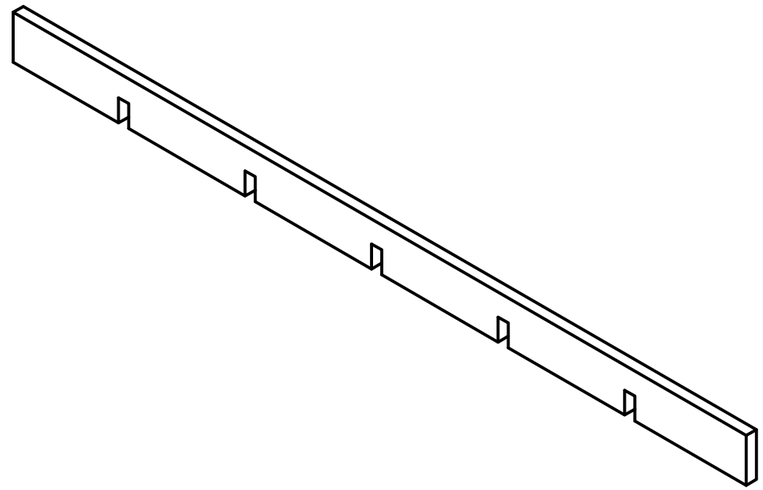

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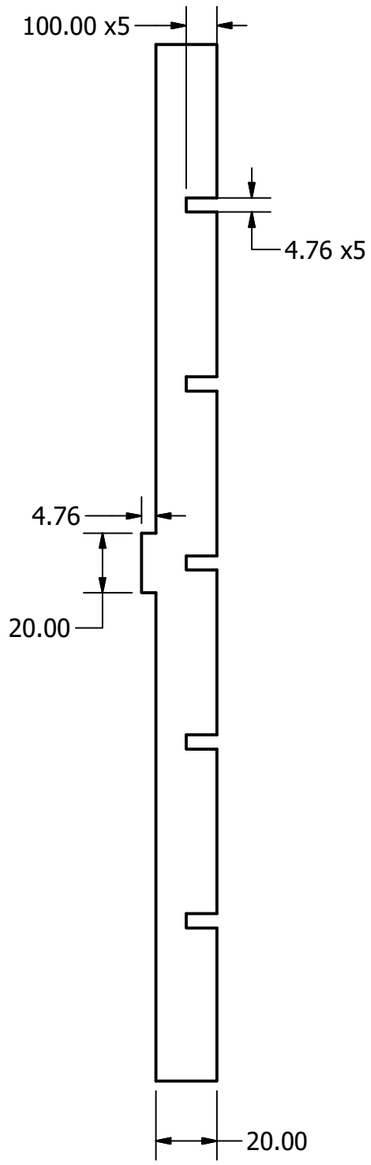

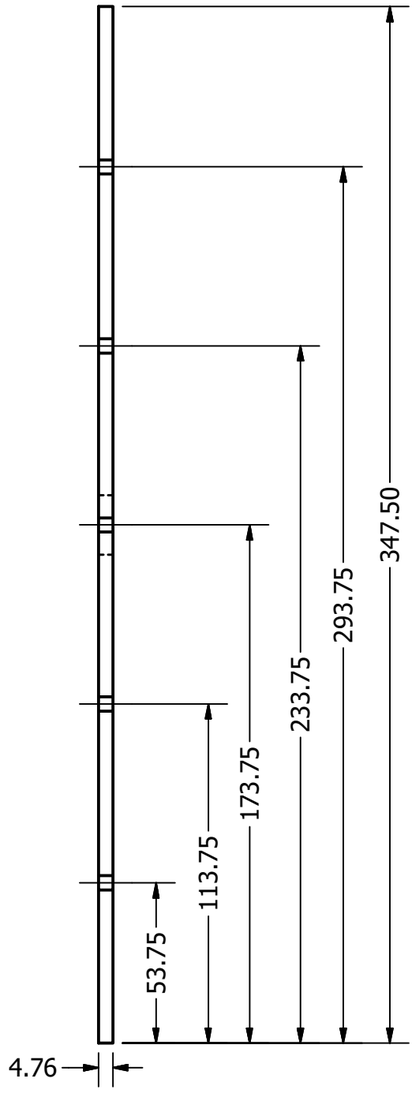

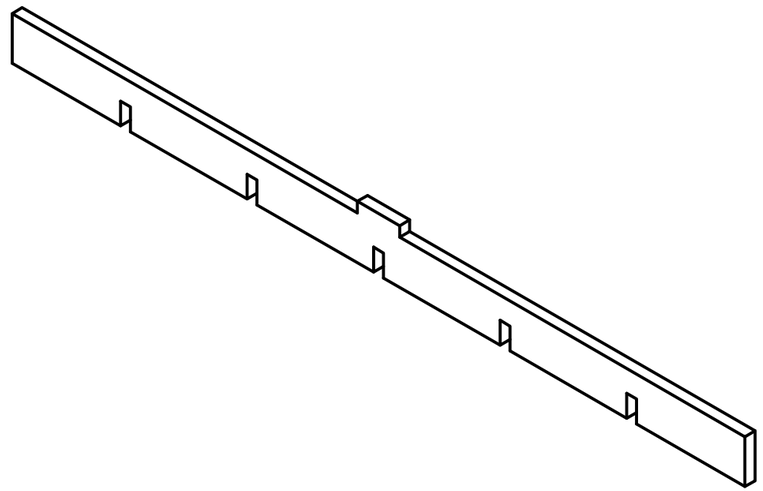

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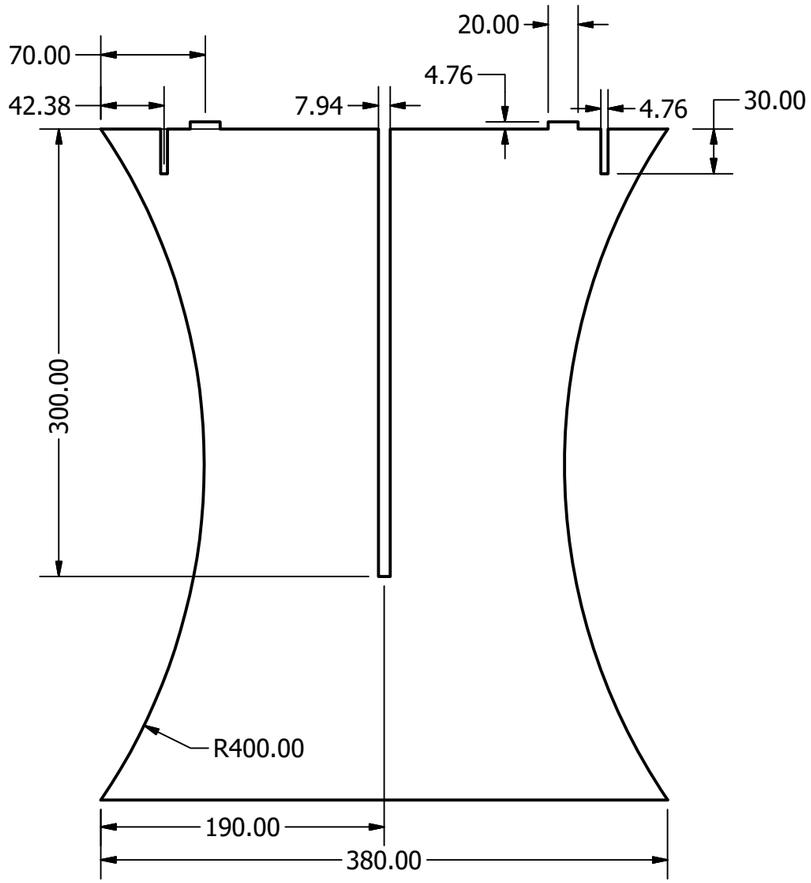
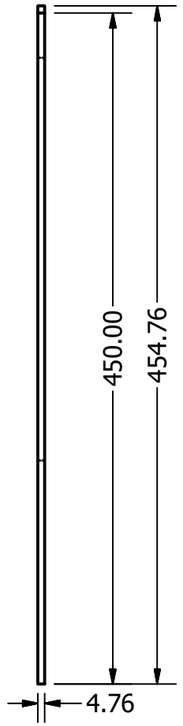
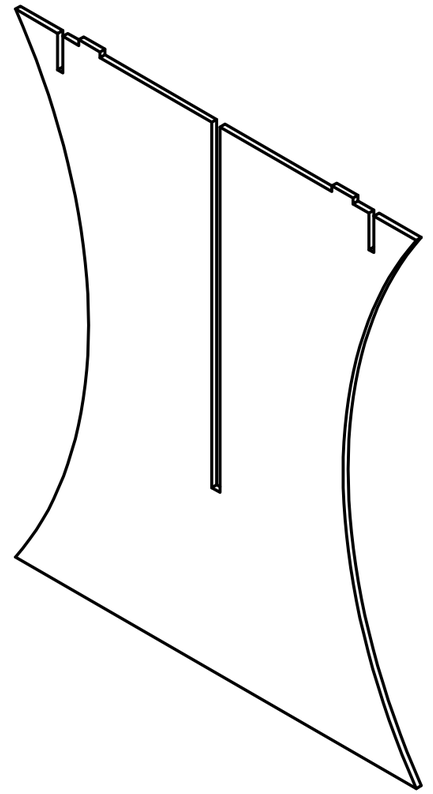
Symmetrical about the center line







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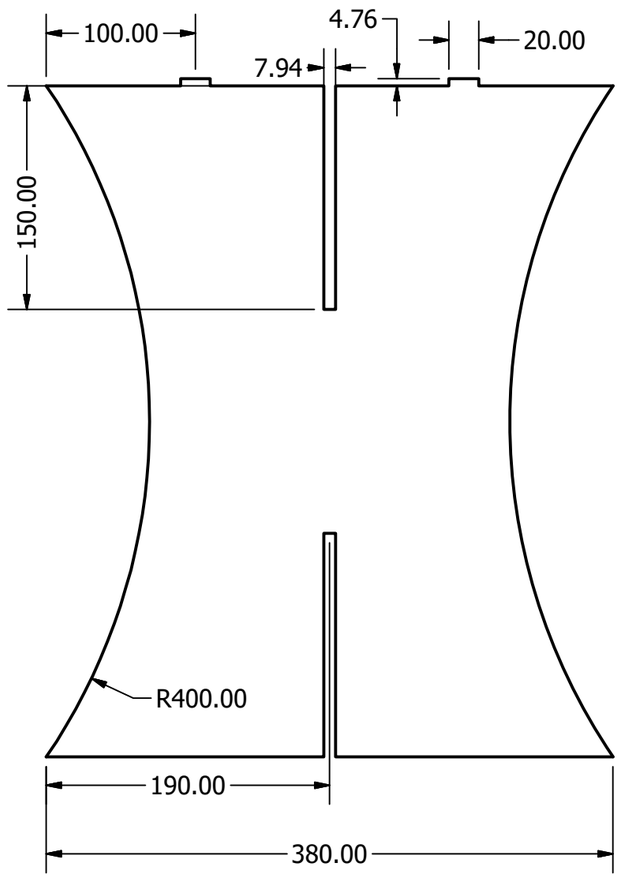

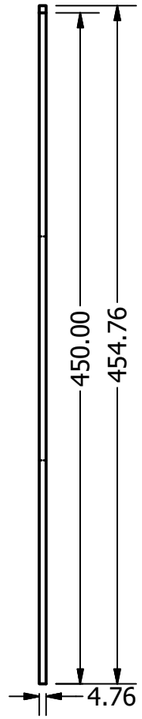

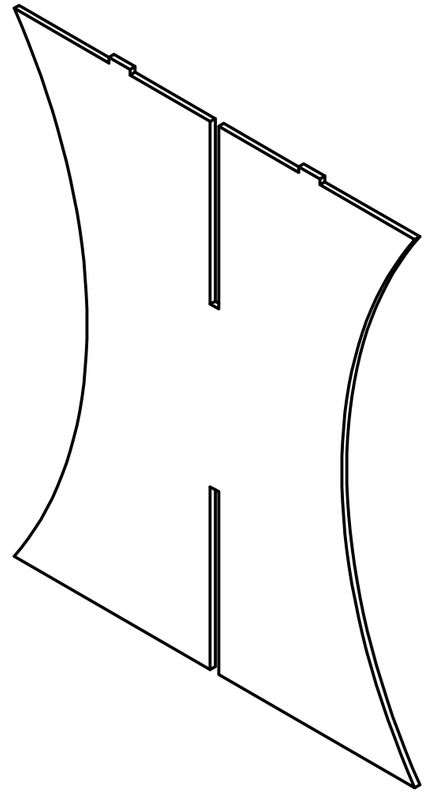

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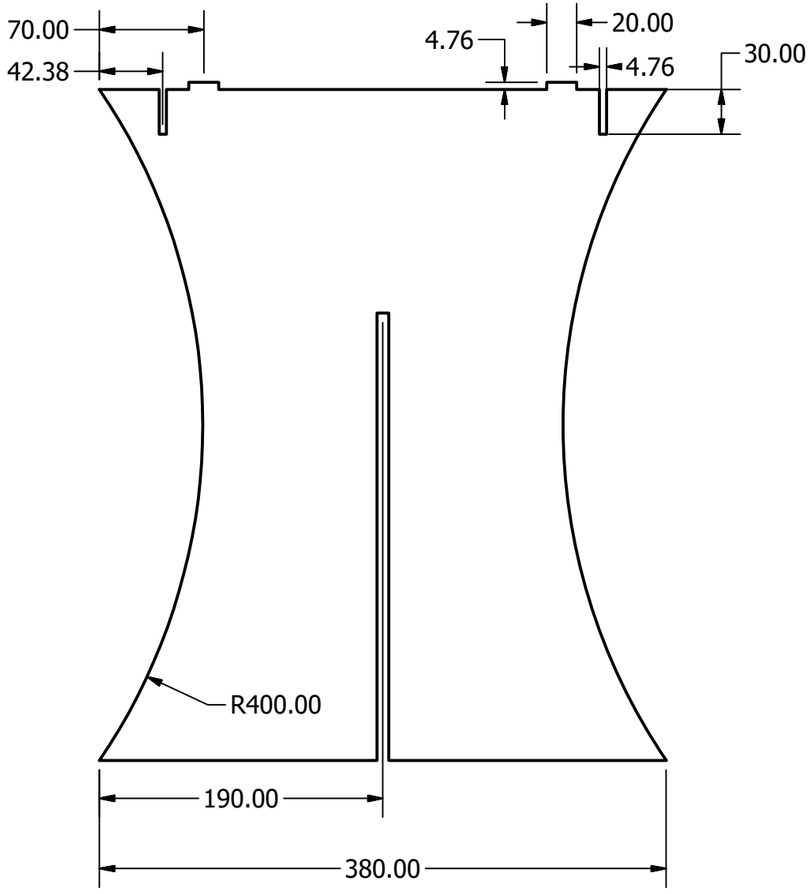
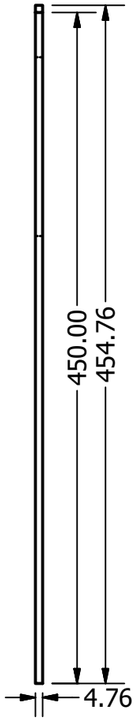
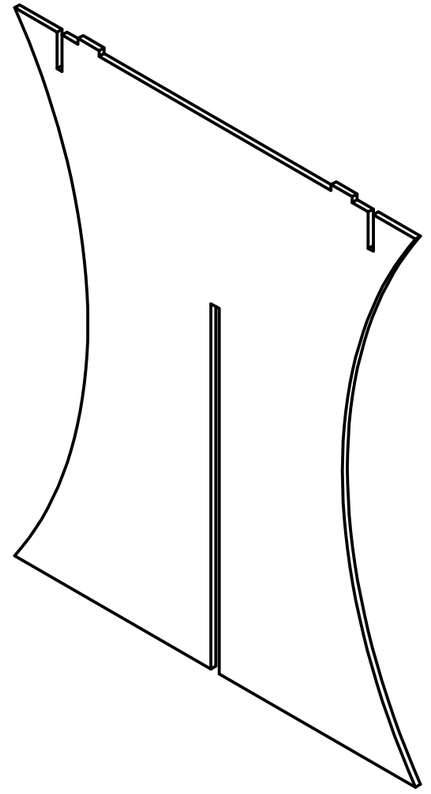
Symmetrical about the center line







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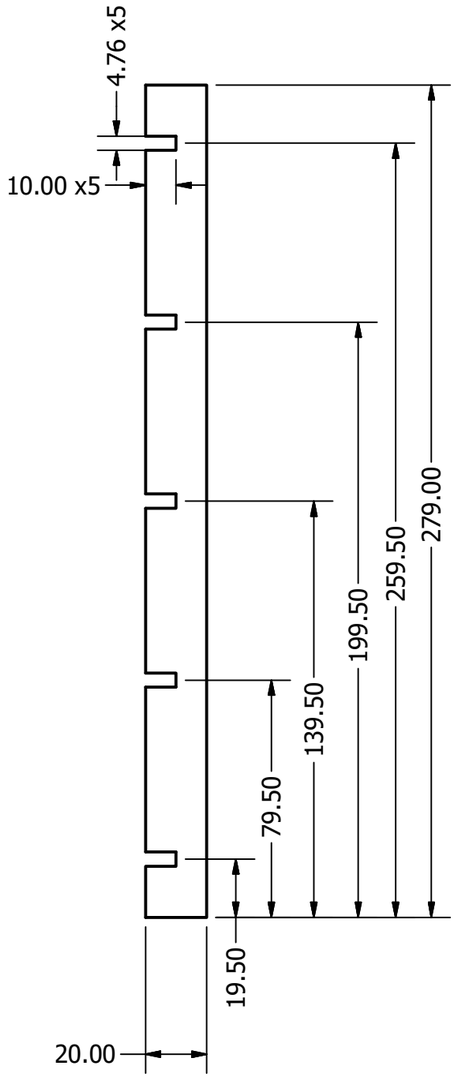
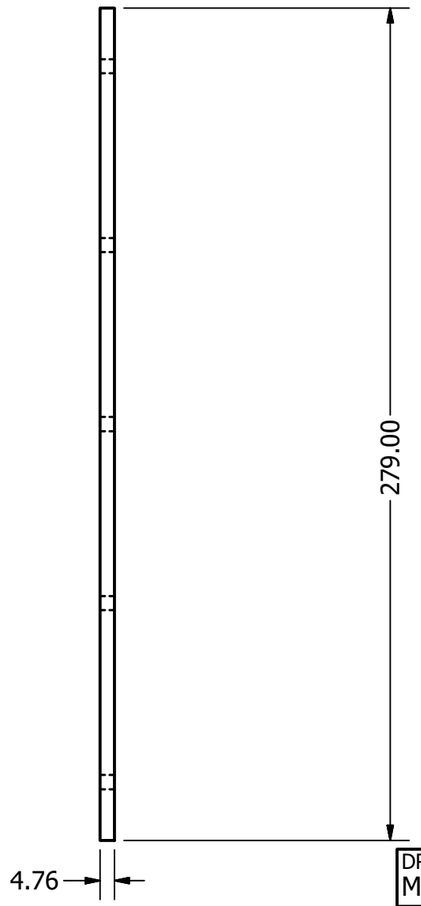
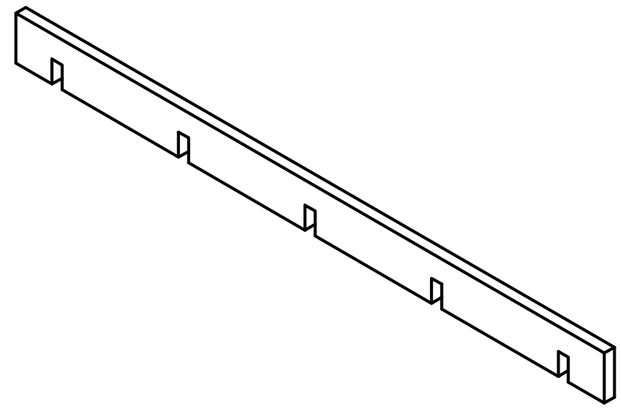
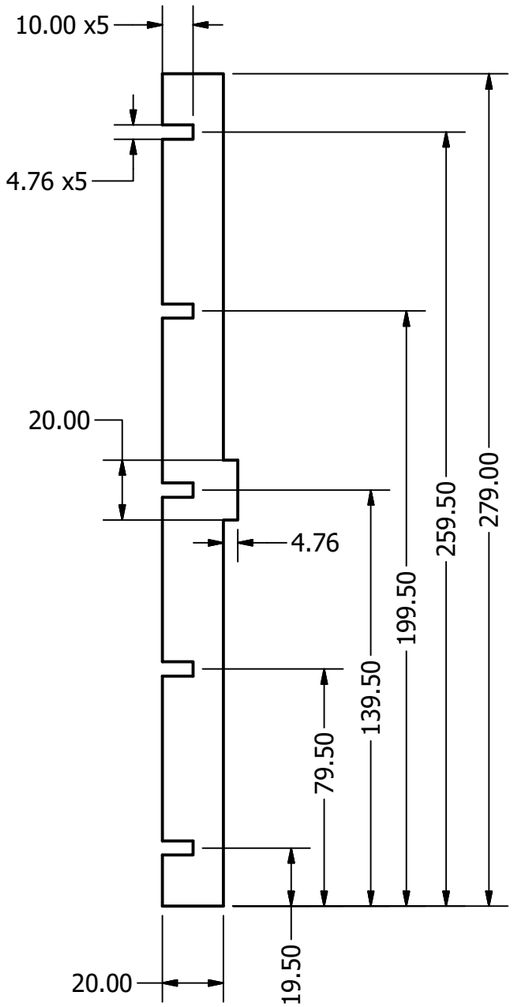
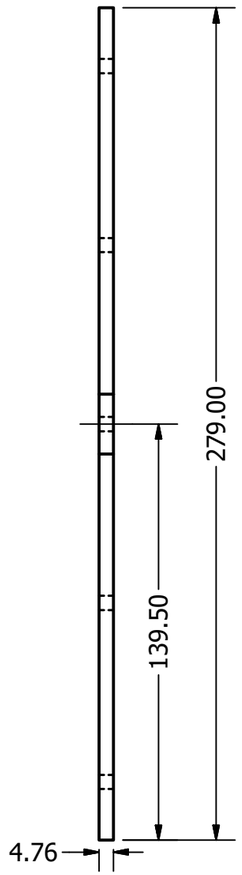


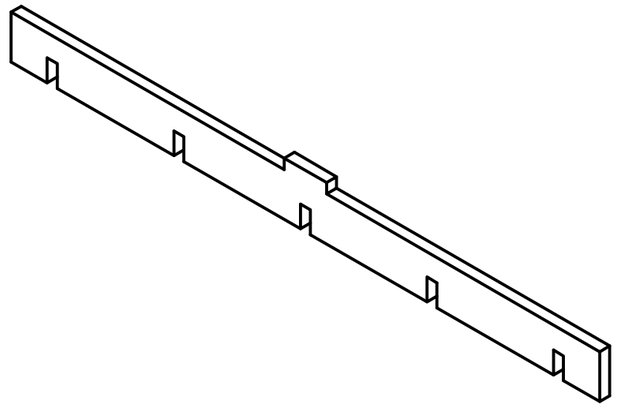




DRAWN Mateusz Rychtarczyk	9/27/2016		
CHECKED			
QA		TITLE Sustainable Chair Project	
MFG			
APPROVED			
		SIZE B	DWG NO Outer Seat Support
		SCALE 1 / 2	SHEET 1 OF 1

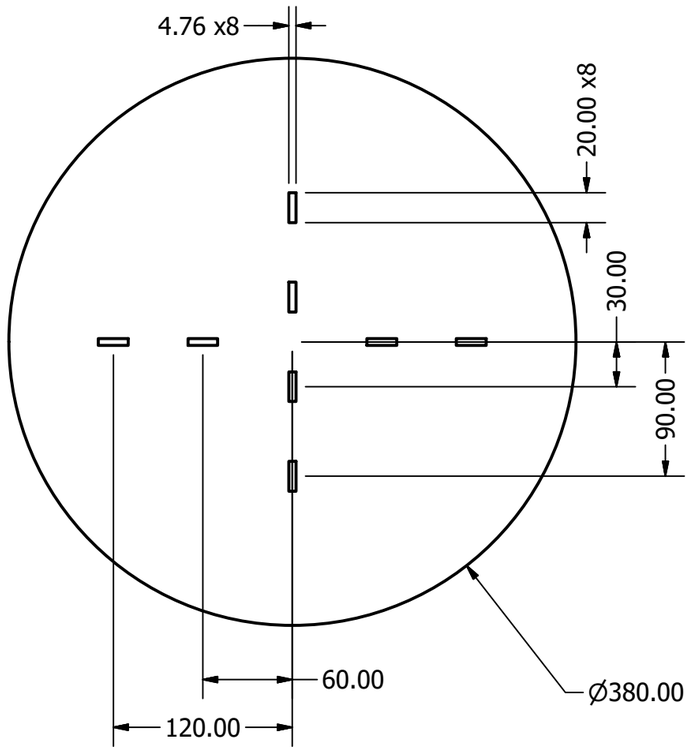


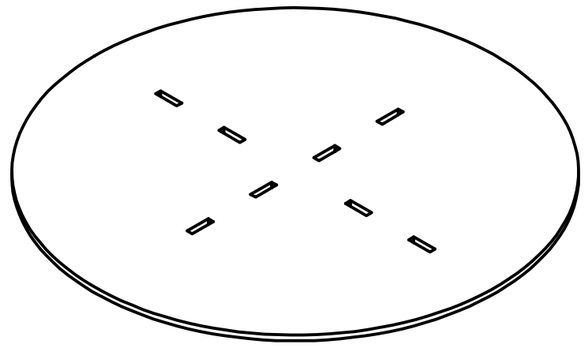


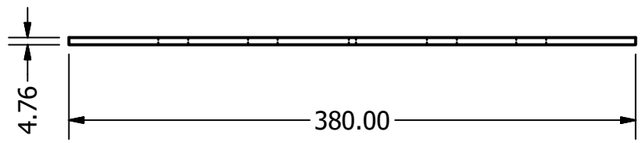


DRAWN Mateusz Rychtarczyk	9/27/2016		
CHECKED		TITLE Sustainable Chair Project	
QA			
MFG			
APPROVED		SIZE B	DWG NO Outer Seat Support
		SCALE 1 / 2	SHEET 1 OF 1

All cutouts are symmetrical







DRAWN Mateusz Rychtarczyk	9/27/2016	
CHECKED		TITLE Sustainable Chair Project
QA		
MFG		
APPROVED		
		SIZE B / DWG NO Top Seat Base / REV
		SCALE 1 / 4 / SHEET 1 OF 1