THE WORKSHOP CHAIR

Design and fabrication of multipurpose wheelchair for physically disabled people

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Spring 2019 – MECA595b

Outline

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Market Research

Project Aim

Alternative Wheelchairs

Outline (continued)

Design

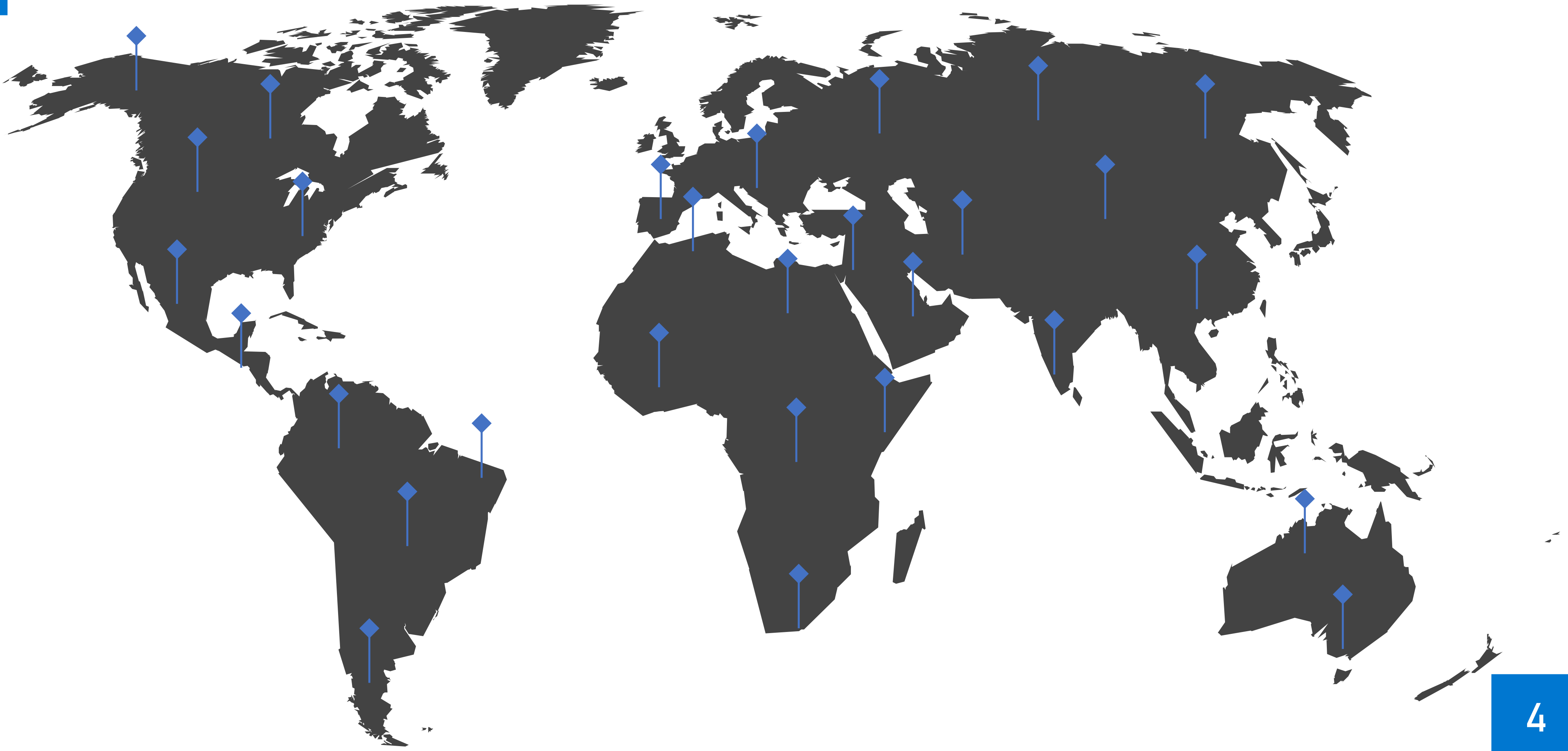
Calculations

Control

Conclusion

INTRODUCTION

WORLD MAP



1,000,000,000 PERSON

According to World Bank Group

IN LEBANON

15% OF LEBANESE POPULATION

Lebanese people living in Lebanon

10% OF PALESTINIAN REFUGEES and 22.8% OF SYRIAN REFUGEES

whom fled to Lebanon because of war

DISABILITIES

- Vision Impairment
- Deaf or hard of hearing
- Health conditions
- Physical disability

Etc.

140,000

OUT OF THE 900,000

DISABLED LEBANESE HAS

PHYSICAL DISSABILITY

INEQUALITY

- Economic
- Social
- Political

WORKSHOP CHAIR

WORKSHOP CHAIR

A personal positioning device uniquely designed for lifting and lowering the human body for work under and around virtually anything

WORKSHOP CHAIR

MARKET RESEARCH

IN LEBANON

STUDY

Sample of 200 randomly chosen physically disabled people
Aged between 14 and 40 years

Disabled people and Education

- In Lebanon, most mainstream schools exclude children with disabilities.
- Education quality for disabled children in institutions is low.

→ almost half were not promoted from primary

- Younger graduates are scoring significantly lower than older graduates.

→ only 23 percent of the 14-20 age group had been promoted from primary school whereas were 40 years old completed their education

Disabled people and Employment

- In Lebanon, most disabled people are jobless.

→ 45.5 % of the sample were employed

→ 50.5% were unemployed, including the “discouraged workers”

- One of the most worrying findings of the study was that young people were scoring lower in educational attainment, and were also more likely to fail in the market.

PROJECT AIM

Project Aim

This chair is designed especially for physically disabled millennials who would like to work in industrial and automation fields.

ALTERNATIVE WHEELCHAIRS

DIFFERENT WHEELCHAIRS

There are 3 types of electronic wheelchairs other than the well-known manual one.

Scewo Bro Wheelchair

In addition to its normal driving mode, Scewo Bro has rails that allows the user to drive in natur e on bumpy or muddy roads. It also can climb stairs at a 1 step per second. Furthermore, it can i ncline up to 47 degrees.

WHILL Model M Wheelchair

It can cross over obstacles 3 inches high due to its large omni wheels that can move in any direction. It is powered by 2, 12V 50Ah Batteries that uses a 6A charger.

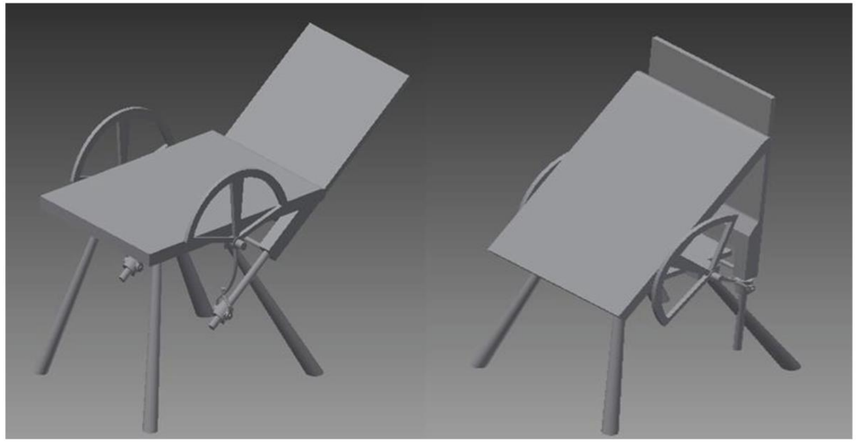
KD Foldlight Wheelchair

It is electronic wheel chair that has the ability to fold and become easy to carry.
Also, it is airline friendly wheel chair

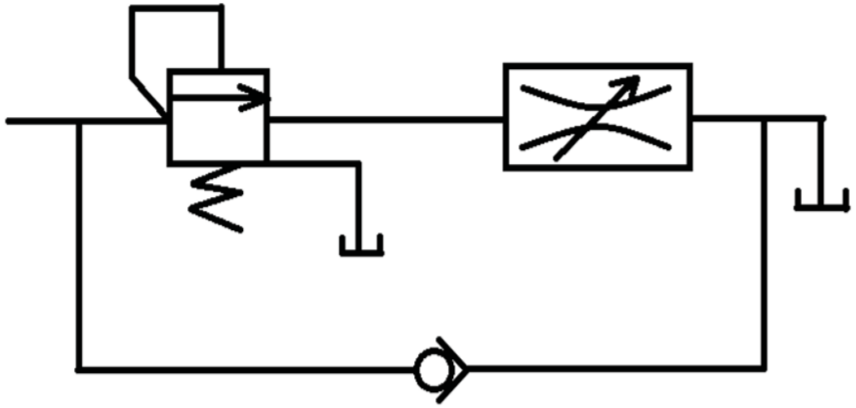
STANDING MECHANISMS

Standing wheelchairs

→ Principle of folding chair

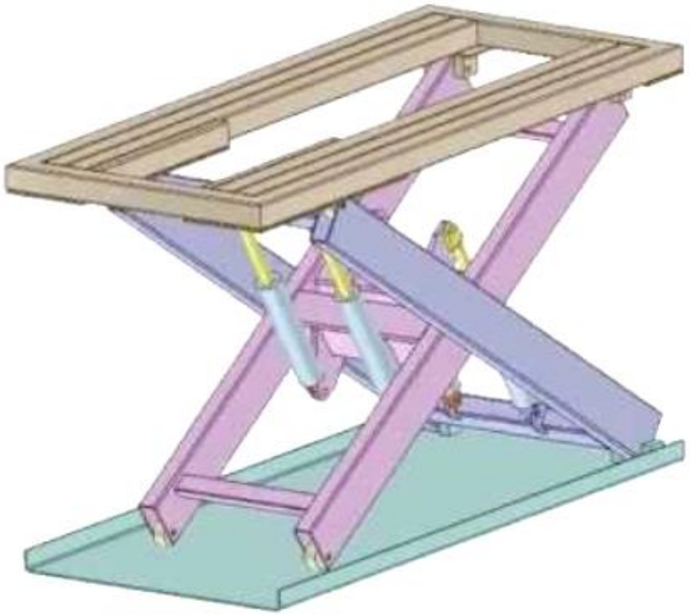


→ Hydraulic control system



Standing wheelchairs

→ Scissors Mechanism



DESIGN

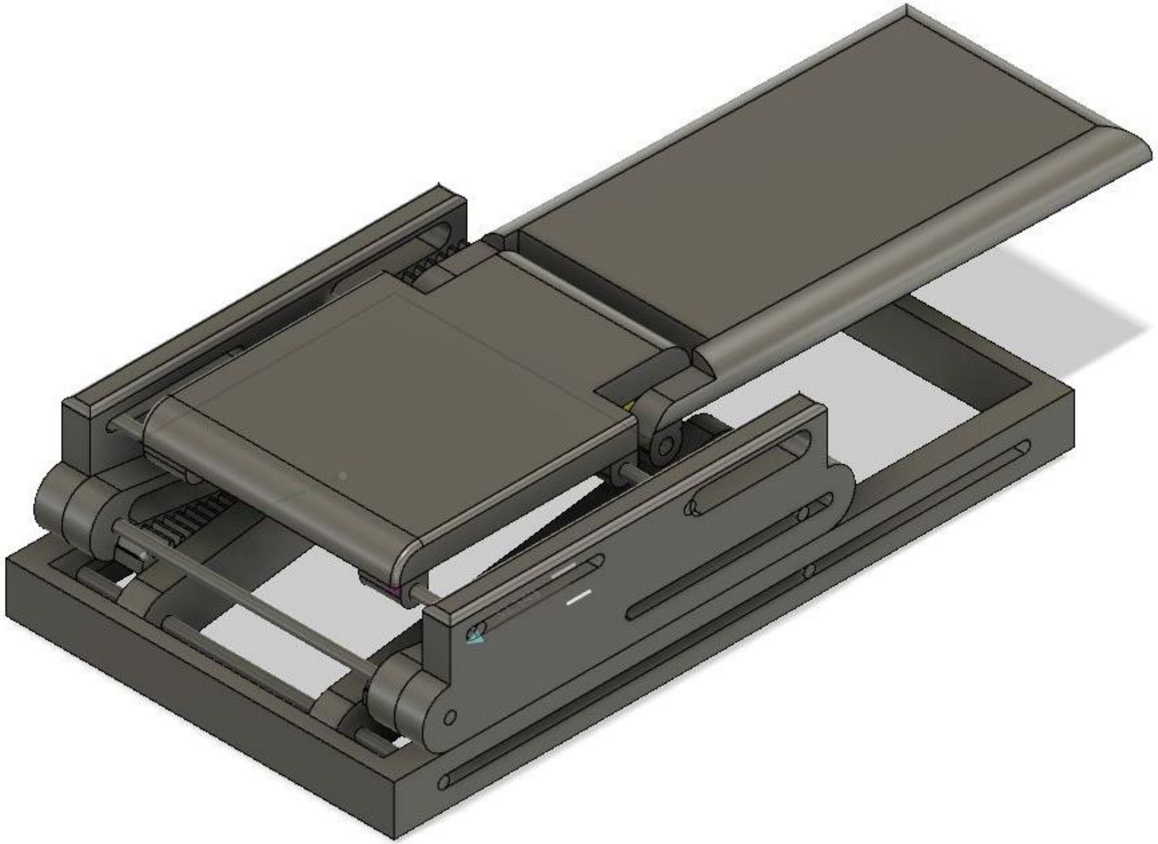
Targeted postures

Positions

Positions

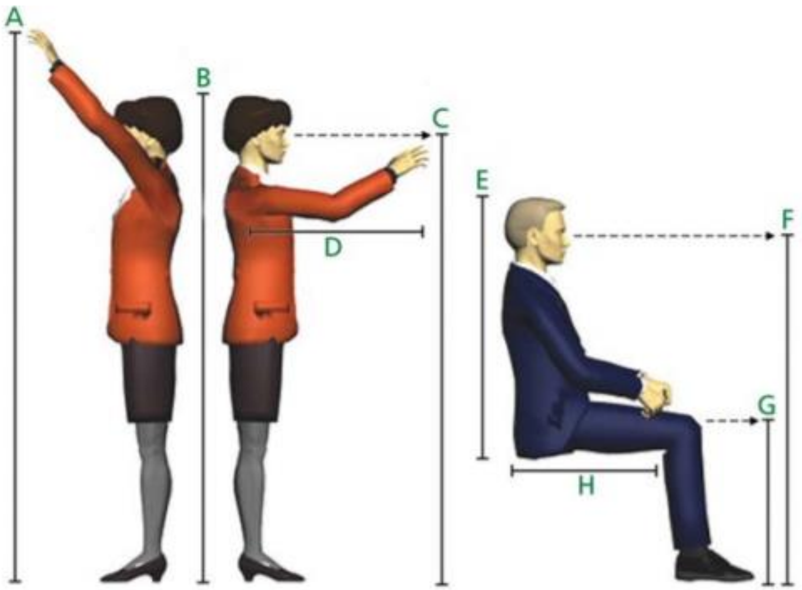
Positions

Positions



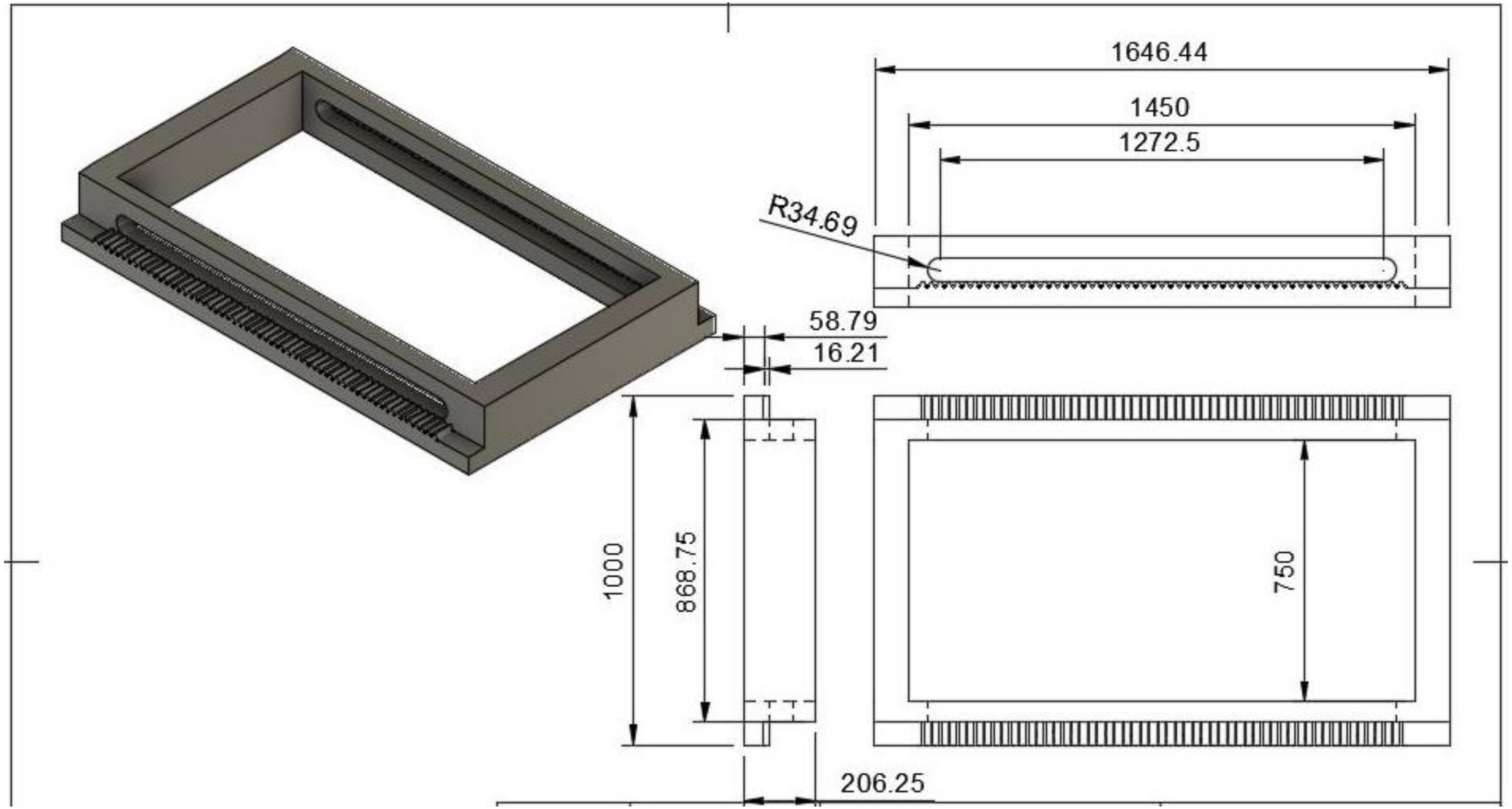
Chair's Dimensions

Anthropometric measurements

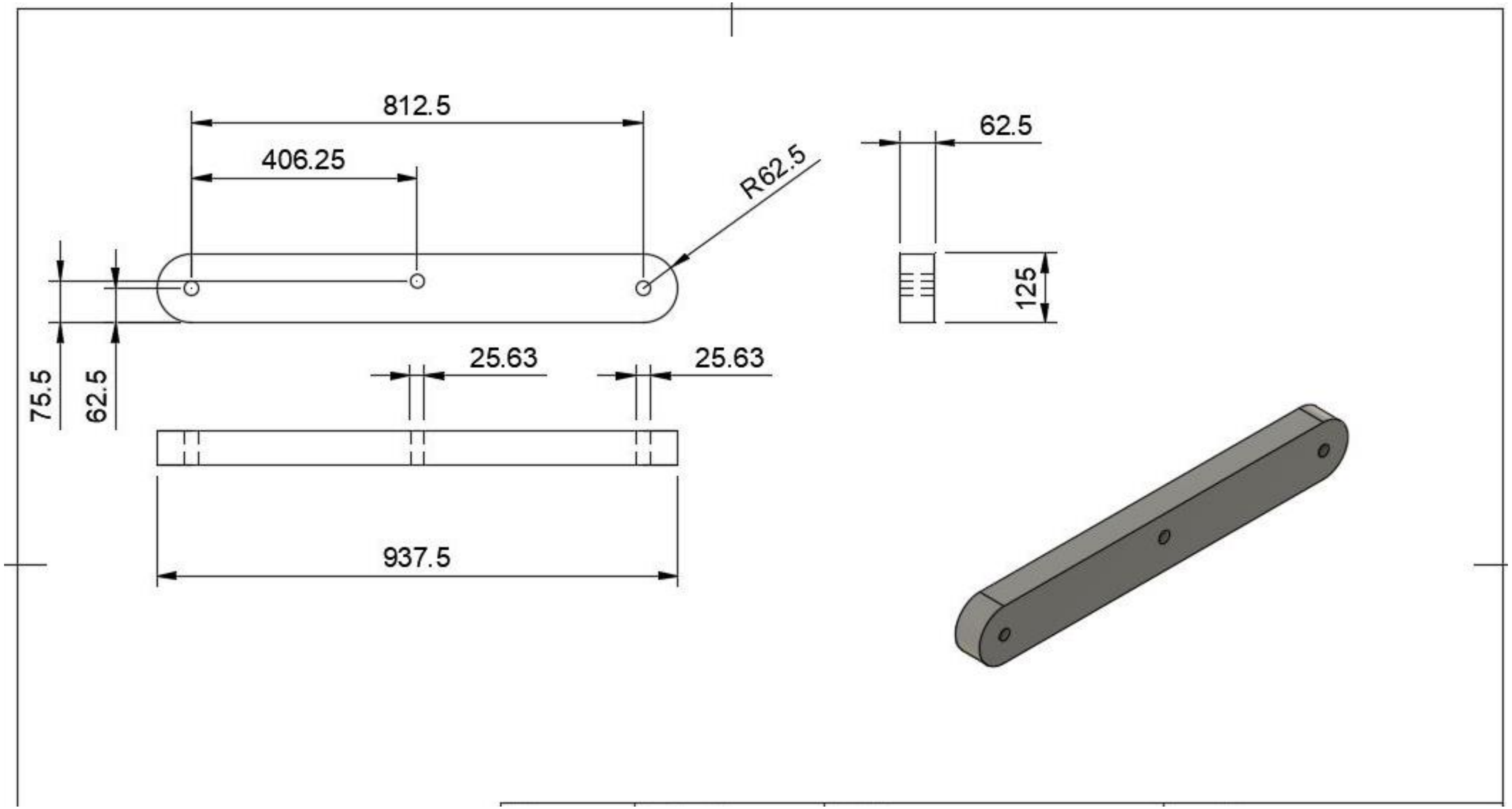


Measurement	Letter	Female	Male
Standing Overhead Reach	A	74.9" – 86.8"	81.2" – 93.7"
Standing Height	B	60.2" – 68.4"	64.8" – 73.5"
Standing Eye Height	C	56.9" – 65.0"	61.4" – 69.8"
Standing Forward Reach	D	30.8" – 36.1"	33.8" – 39.5"
Sitting Height	E	31.3" – 35.8"	33.6" – 38.3"
Sitting Eye Height	F	42.6" – 48.8"	46.3" – 52.6"
Sitting Knee Height	G	19.8" – 23.2"	21.4" – 25.0"
Seat Depth	H	16.9" – 20.4"	17.7" – 21.1"

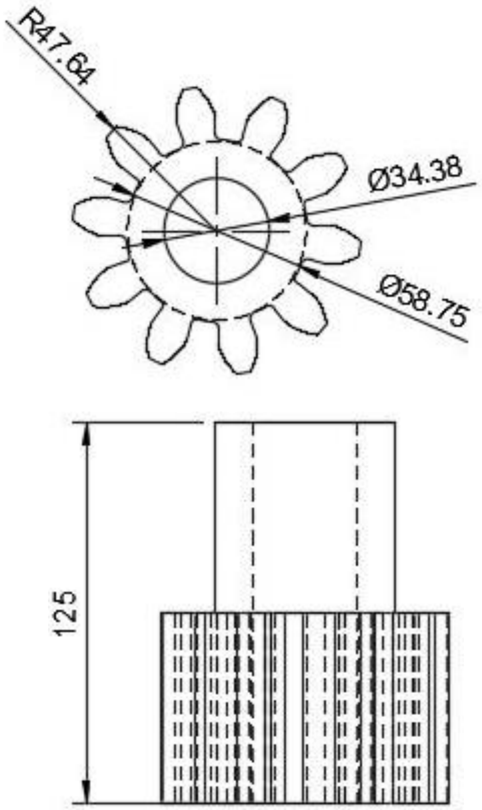
Base

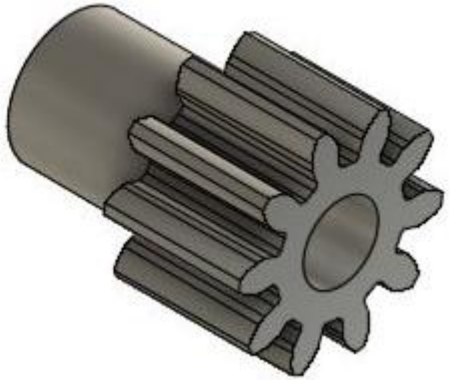


Beam

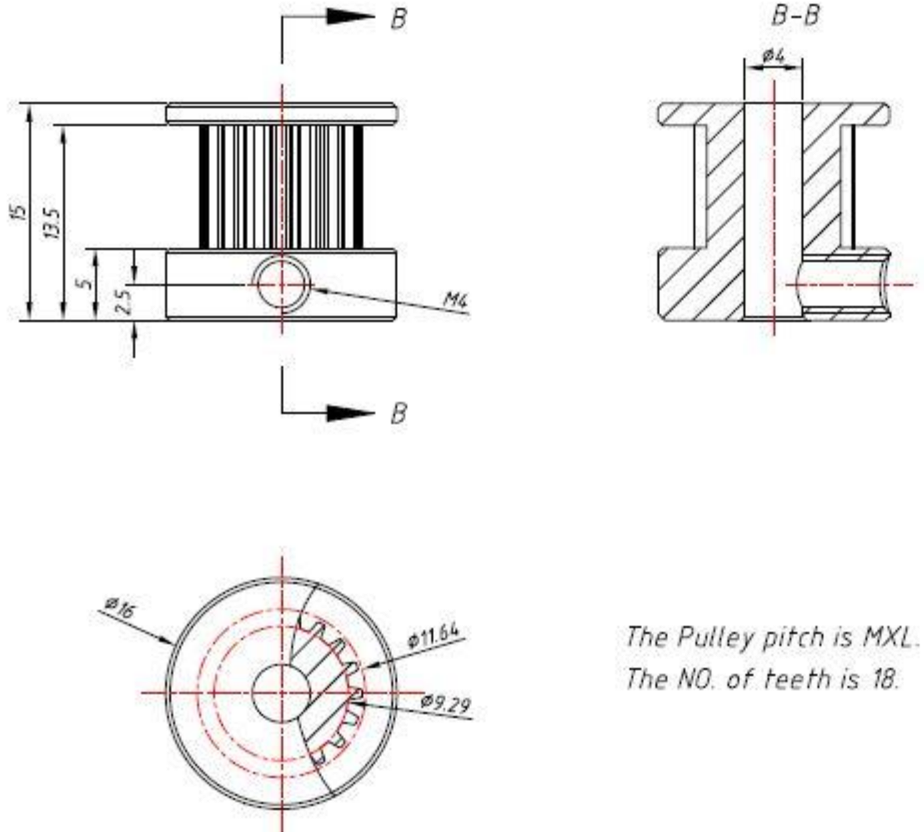


Gear



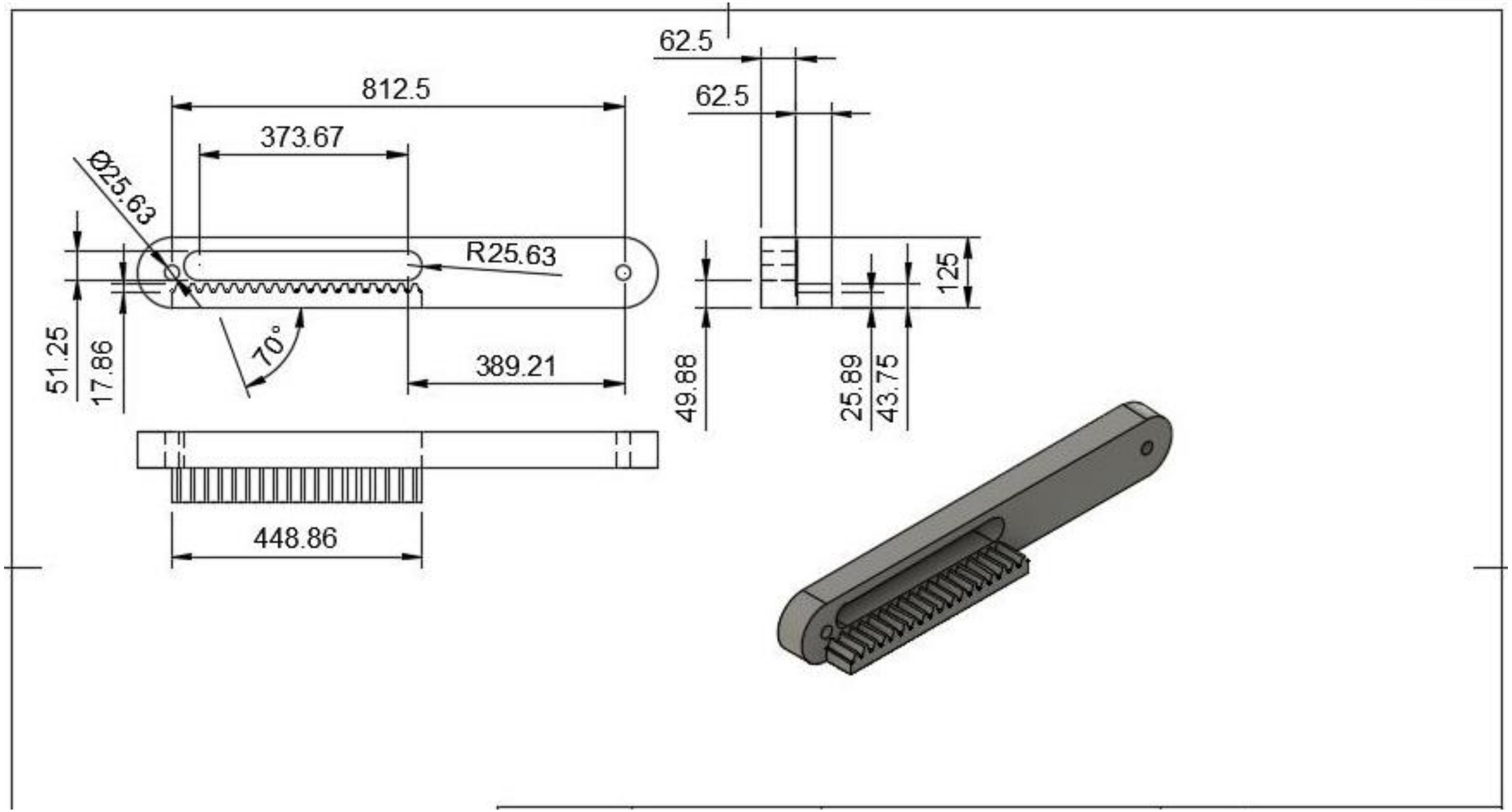


Pulley

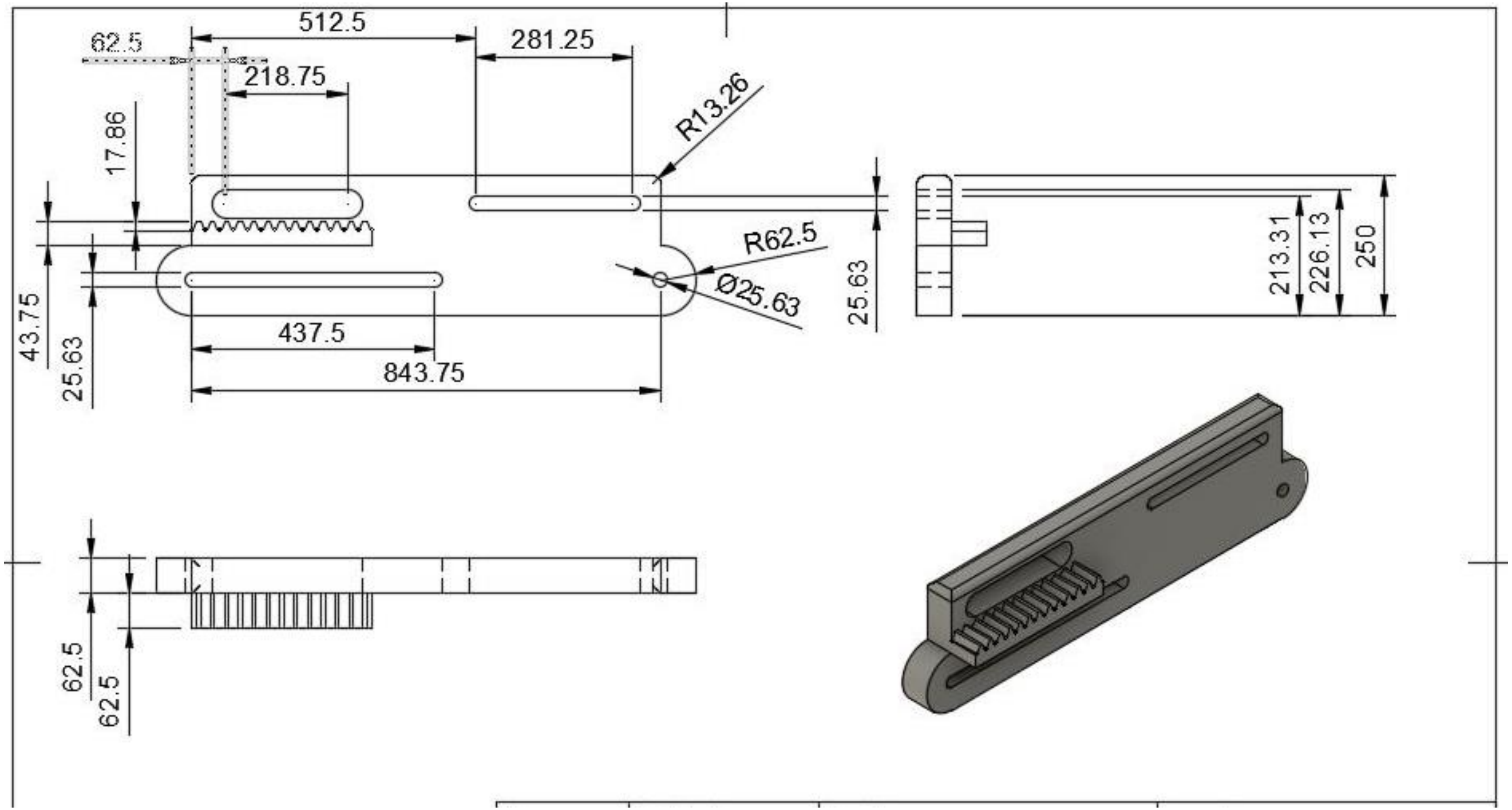


The Pulley pitch is MXL.
The NO. of teeth is 18.

Racked Beam

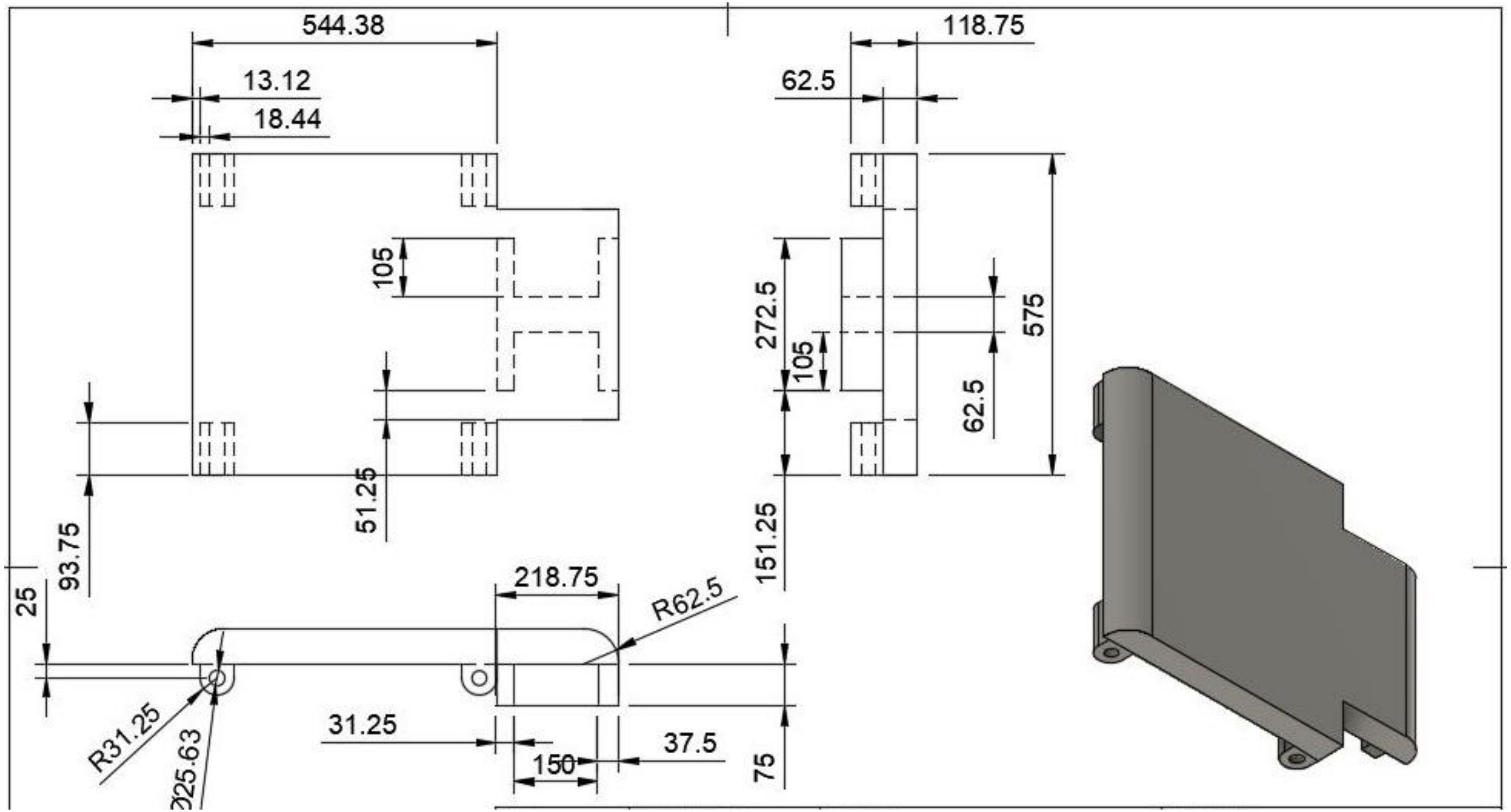

62.5
62.5
812.5
373.67
Ø25.63
R25.63
51.25
17.86
70°
389.21
49.88
25.89
43.75
125
448.86

Seat Frame



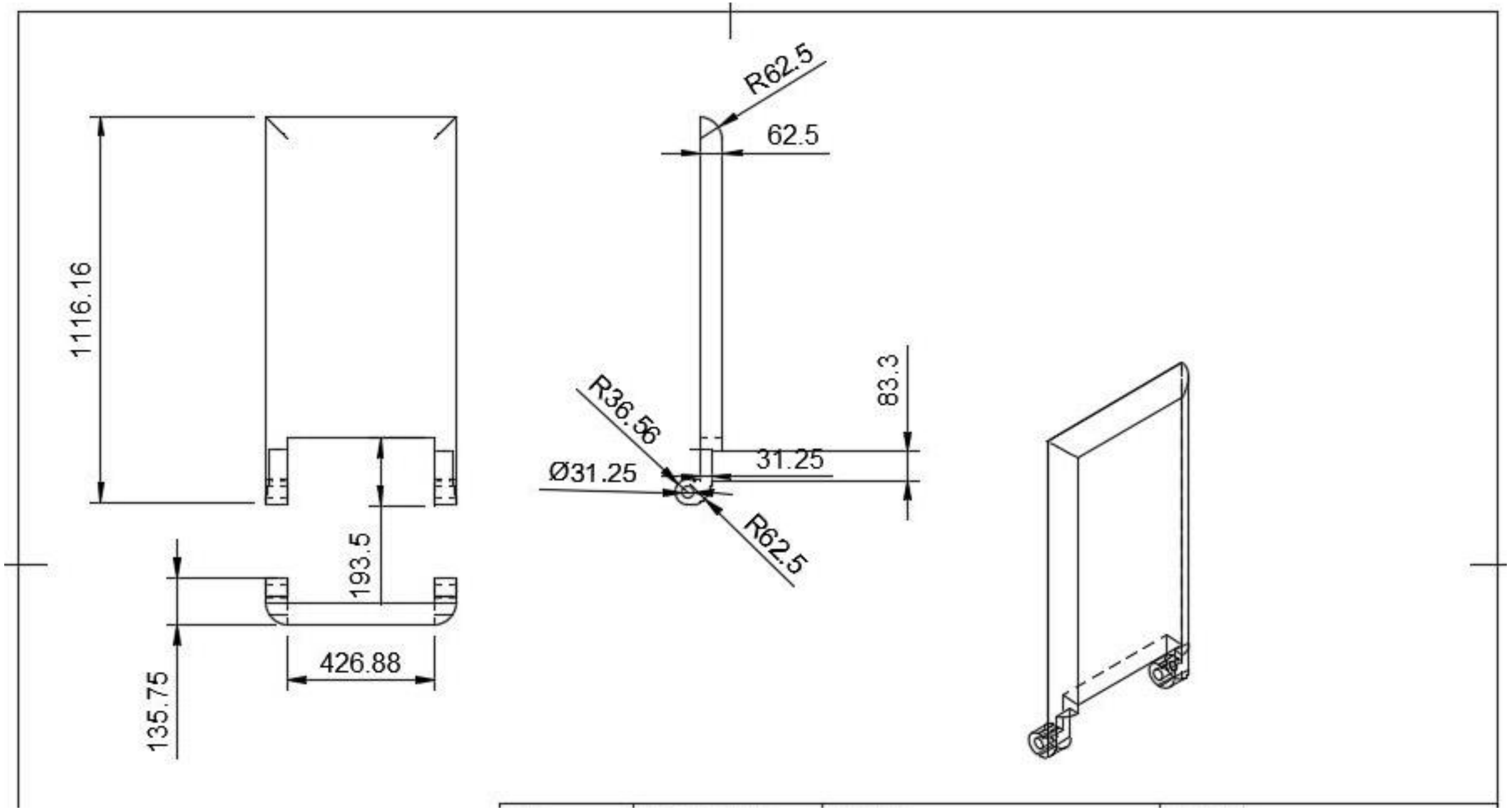
512.5
62.5
281.25
218.75
R13.26
17.86
R62.5
Ø25.63
43.75
25.63
437.5
843.75
25.63
213.31
226.13
250
62.5
62.5

Seat



544.38
13.12
18.44
105
51.25
93.75
25
218.75
R62.5
R31.25
Ø25.63
31.25
150
37.5
75
118.75
62.5
272.5
105
575
62.5
151.25

Back



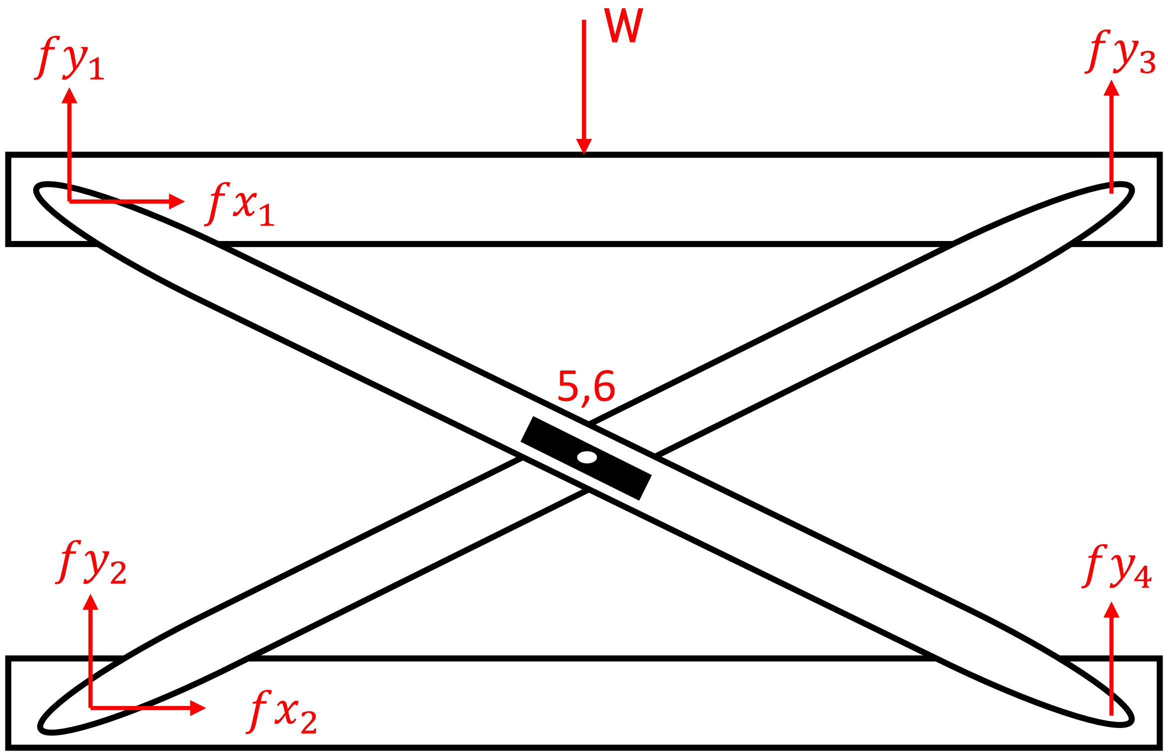
CHAIR'S ASSEMBLY

Assembly

MECHANICAL DESIGN

Stress Analysis

Free Body Diagram of Scissors Mechanism



Assumptions

- 1, 2, 3 and 4 (points) are rollers (gear)
- 1 and 2 motors are DC braked
- 3 and 4 can move
- W is the weight of the user.

External Reactions

$$\sum Fx = 0$$

$$fx_1 = fx_2$$

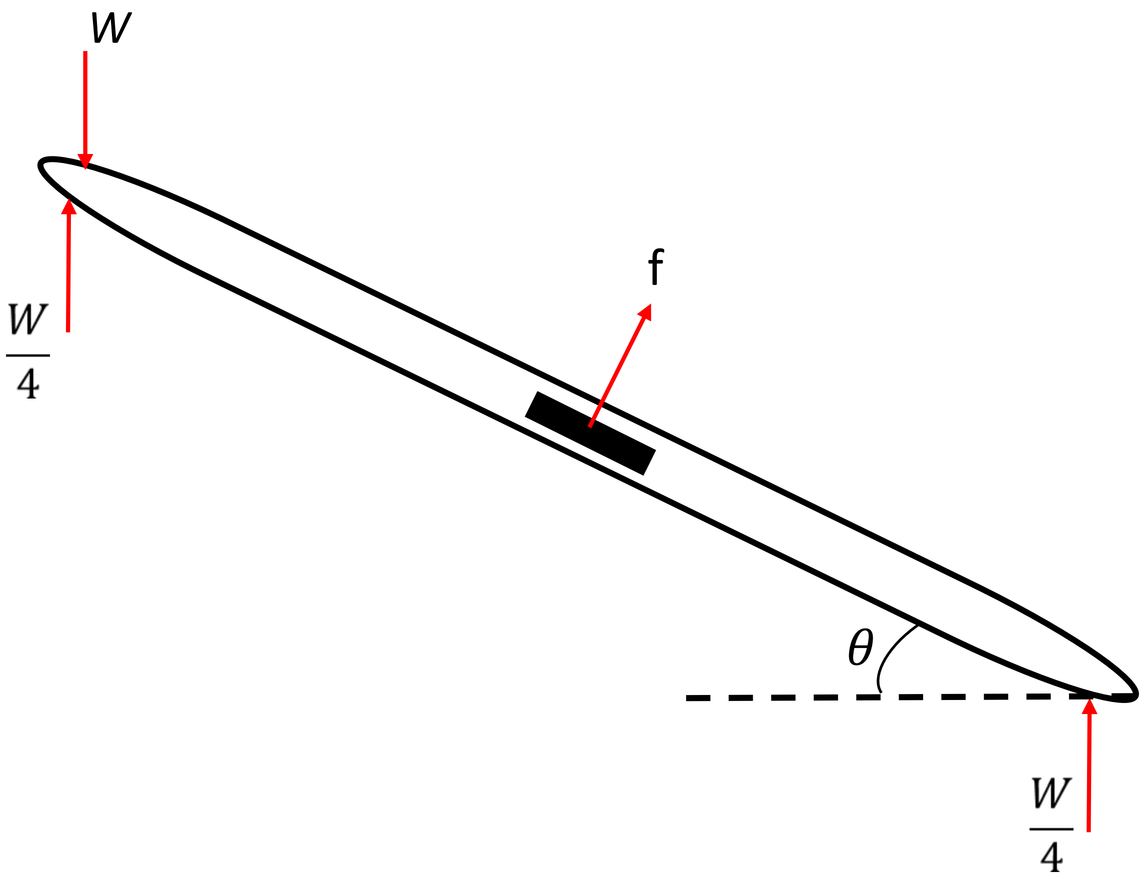
$$\sum Fy_1 = 0$$

$$fy_1 + fy_2 + fy_3 + fy_4 - W = 0$$

But assuming $$fy_1 = fy_2 = fy_3 = fy_4$$

Then, $$\frac{W}{4} = fy_1 = fy_2 = fy_3 = fy_4$$

Free Body Diagram of link with joint



Internal Reactions – 1

$$\sum Fy = 0$$

$$f\cos\theta + \frac{W}{4} + \frac{W}{4} - W = 0$$

Assuming θ will be determined to fit a normal sitting state

$$f = \frac{\frac{w}{2}}{\cos\theta}$$

Implies the reaction force of the prismatic

Internal Reactions – 2

$$\sum Fx = 0$$

$$fp_x sin\theta + f sin\theta + fp_y cos\theta = 0$$

$$\sum Fy = 0$$

$$-fp_x cos\theta + f cos\theta + fp_y sin\theta = 0$$

Yields a system of 2 equations with 2 unknowns to find the reaction forces of fp_x & fp_y

Fatigue Failure Analysis

Internal Reactions – 2

$$R_1 = R_2 = \frac{W}{4} = \frac{300 \times 9.81}{4} = 735.35\ N$$

Cut at A

$$\sigma_A = -\frac{My}{I} = -\frac{(735.35 \times 0.5cos70)(\frac{0.125}{2})}{\frac{1}{12} \times 300 \times 1^2} = -0.31\ Pa$$

$$\sigma_{max} = k_f \times \sigma_A = 1.7\ \times -0.31 = -0.527\ Pa$$

From property graphs of aluminum, it is found that $S_{ut} = 758.5\ Pa$

$$S_e = k_a k_b k_c k_d k_e S_{e'} = 190\ Pa$$

Since $\sigma_{max} \ll S_e\ \rightarrow N = infinity$

CHOOSING ACTUATORS

Degrees of Freedom

DOF ≡ Nº of Motors

According to Gruebler's formula applied on a 3D body,

$$DOF = 6(N-1-J) + \sum_{i=1}^{J} f_i$$

We had the first part, the back with seat slider having 1 DOF, the scissors mechanism having 3DOF and finally the wheels having 2 DOF for forward and backward motion.

Hence, we can conclude that we will need to use a maximum of 6 motors in total.

Wheels' Torque

Torque

$$m_{total} = 120 + 180 = 300\ kg$$

$$W = m_{total} \times g = 2{,}943\ N$$

$$\frac{W}{4} = 735.75\ N$$

Hence, the force in the y-direction will be $f_{fr} = \mu_s N = 0.8 \times 735.75 = 588.6\ N$

The equation of torque is given by $T = I.\alpha = F.r.sin\theta$

Since the wheelchair is in sitting position, then angle between the back and the seat will be $\theta = 90°, then\ sin\theta = 1$

$\therefore T = 600 \times r\ N.m$ where r is the radius of the wheel.

Motors' Torque

Rack and Pinion Torque of Seat

In this part, we will consider that standing position will be the critical position.
In the y-direction,

$$\sum f_y = 0 \rightarrow F = W = 120 \times 9.81 = 1177.2\ N$$

Using the equation of torque for rack and pinion,

$$T = \frac{F \times d}{2} = \frac{1177.2 \times 0.0182}{2} = 10.71\ N.m$$

Rack and Pinion Torque of Scissors

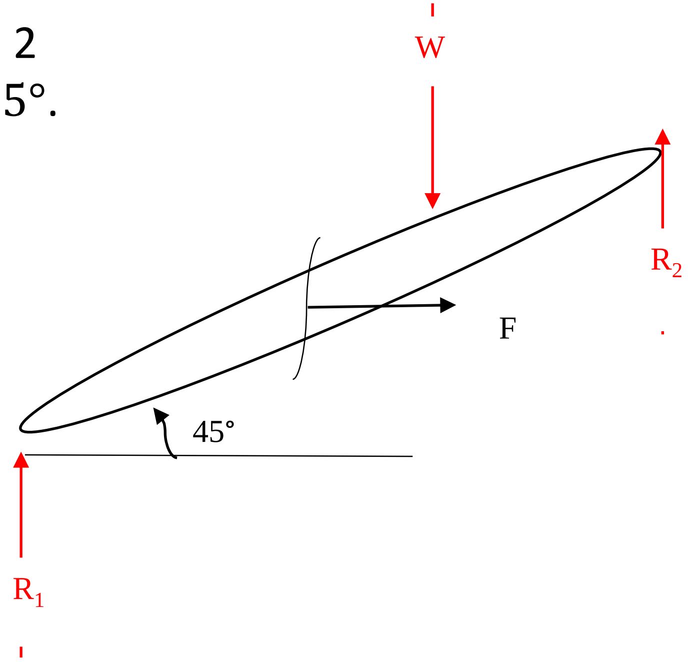
The critical point of the scissors mechanism will be when the 2 rods are perpendicular, then the angle with the base is $\theta = 45°$.

$$-W + \frac{W}{4} + \frac{W}{4} + Fsin45 = 0$$

Then, $Fsin45 = \frac{W}{2} = \frac{(120+40)(9.81)}{2} = 784.8$

$$F = 1110\ N$$

$$\therefore T = \frac{F \times d}{2} = \frac{1110 \times 0.0182}{2} = 10.1\ N.m$$



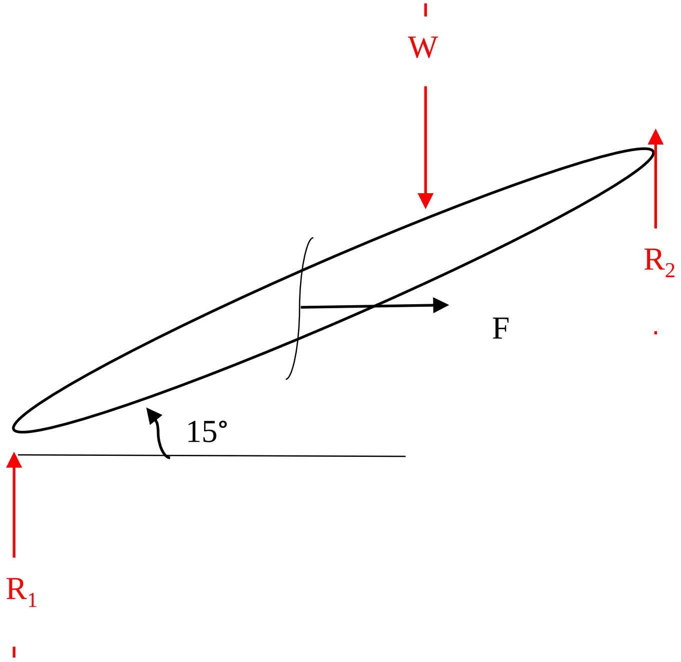
Rack and Pinion Torque of Base

$$-W + \frac{W}{4} + \frac{W}{4} + Fsin15 = 0$$

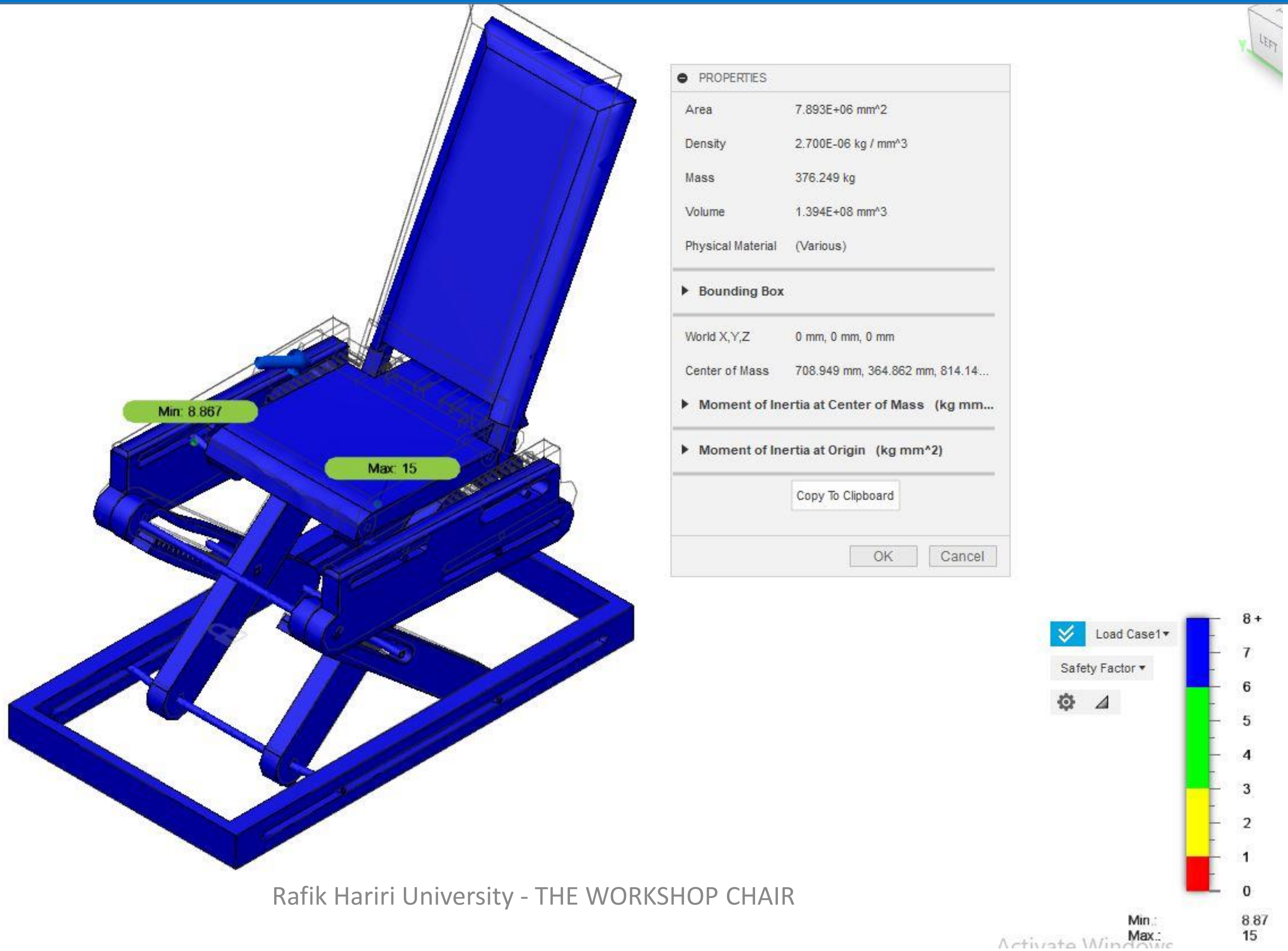
Then, $Fsin15 = \frac{W}{2} = \frac{(120+180)(9.81)}{2} = 1471.5\ N$

$$F = 5685.44\ N$$

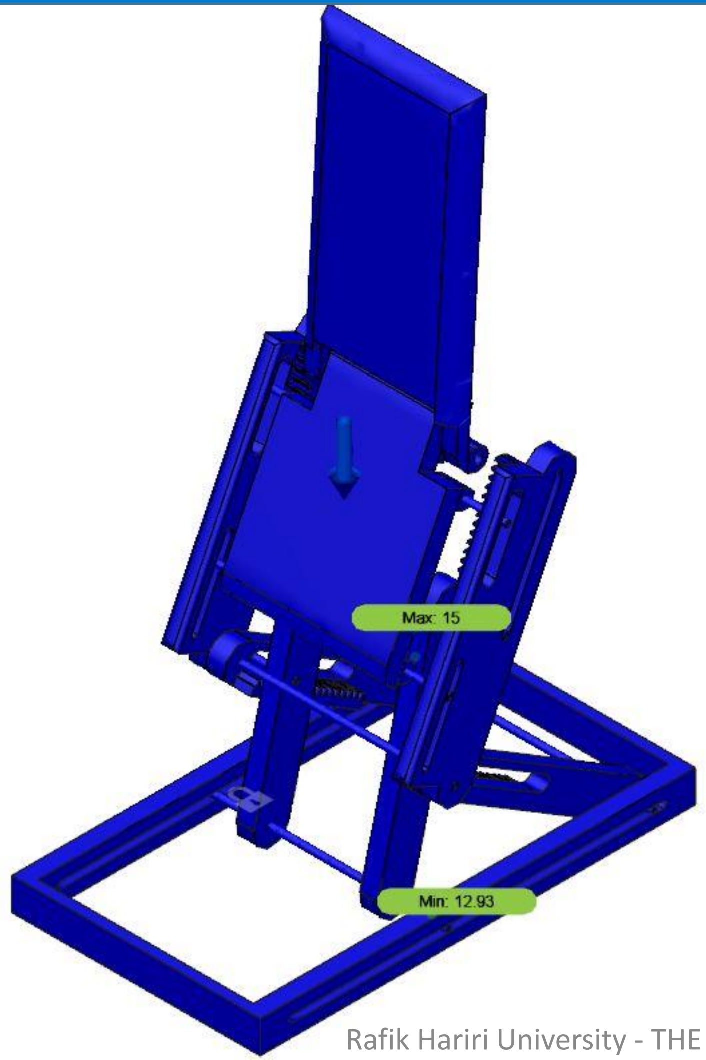
$$\therefore T = \frac{F \times d}{2} = \frac{5685.44 \times 0.0182}{2} = 51.73\ N.m$$

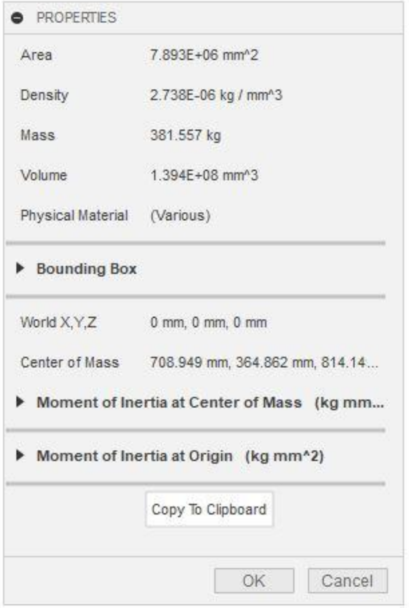


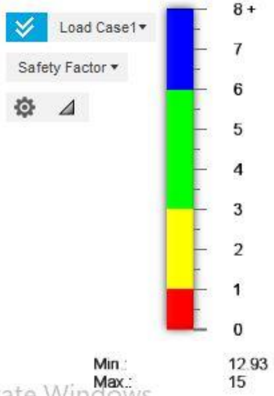
Aluminum – Sitting Position



Aluminum – Standing Position

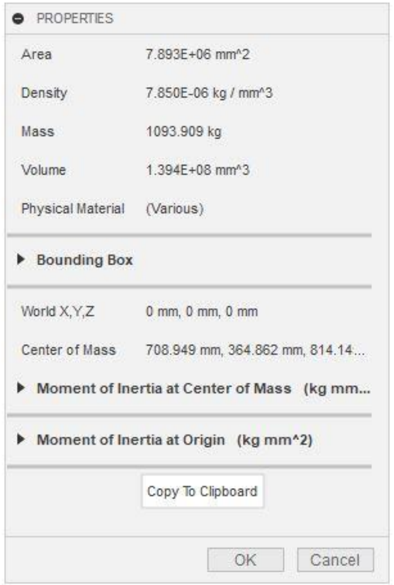


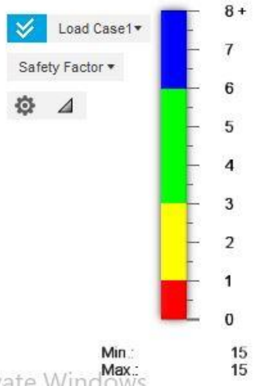




Steel


Max: 15
Min: 15


PROPERTIES
Area 7.893E+06 mm^2
Density 7.850E-06 kg / mm^3
Mass 1093.909 kg
Volume 1.394E+08 mm^3
Physical Material (Various)
Bounding Box
World X,Y,Z 0 mm, 0 mm, 0 mm
Center of Mass 708.949 mm, 364.862 mm, 814.14...
Moment of Inertia at Center of Mass (kg mm...
Moment of Inertia at Origin (kg mm^2)
Copy To Clipboard
OK
Cancel


Load Case1
Safety Factor
8 +
7
6
5
4
3
2
1
0
Min.: 15
Max.: 15

Plastic – Sitting Position

PROPERTIES

Area	7.893E+06 mm^2
Density	1.319E-06 kg / mm^3
Mass	183.826 kg
Volume	1.394E+08 mm^3
Physical Material	(Various)

▸ Bounding Box

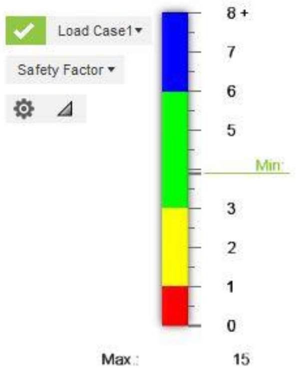
World X,Y,Z	0 mm, 0 mm, 0 mm
Center of Mass	709.207 mm, 364.863 mm, 806.32...

▸ Moment of Inertia at Center of Mass (kg mm...

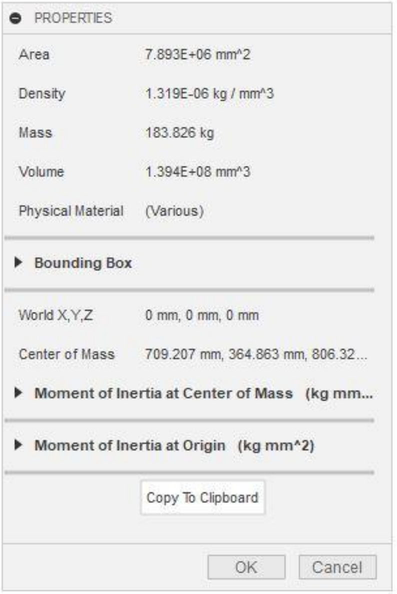
▸ Moment of Inertia at Origin (kg mm^2)

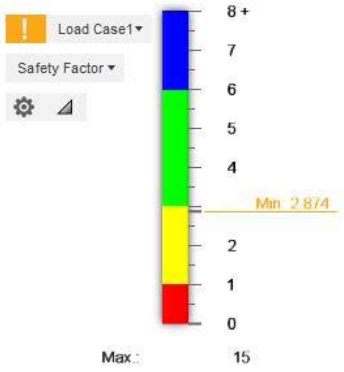
Copy To Clipboard

OK Cancel



Plastic – Standing Position

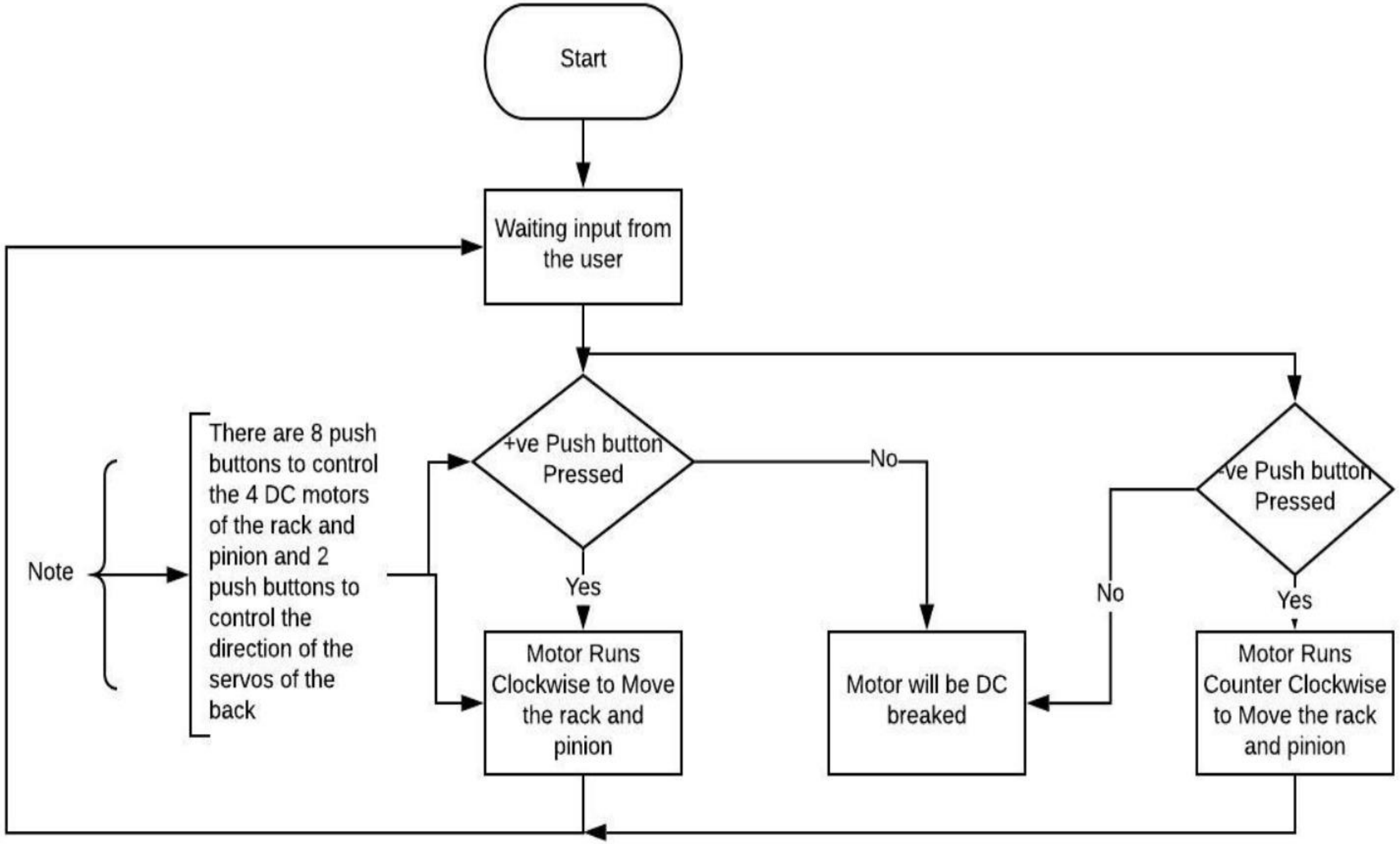




CONTROL

Flowchart

Flowchart



Start
Waiting input from the user
+ve Push button Pressed
-ve Push button Pressed
No
Yes
No
Yes
Note
There are 8 push buttons to control the 4 DC motors of the rack and pinion and 2 push buttons to control the direction of the servos of the back
Motor Runs Clockwise to Move the rack and pinion
Motor will be DC breaked
Motor Runs Counter Clockwise to Move the rack and pinion

Components

Components

Arduino Mega

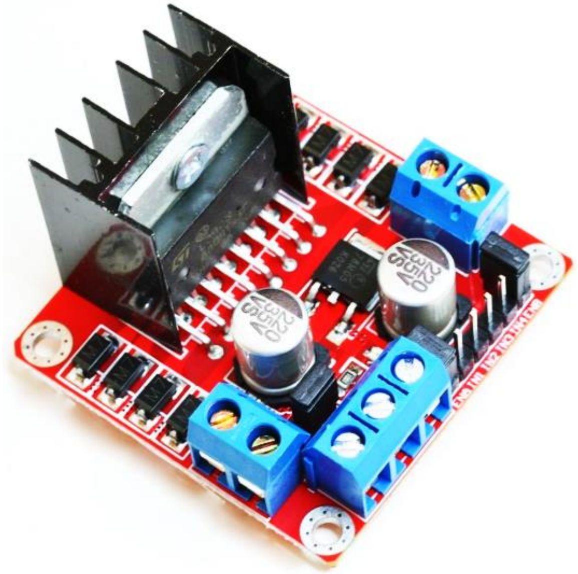
Keypad

Geared DC Motor

Components

Servo Motor

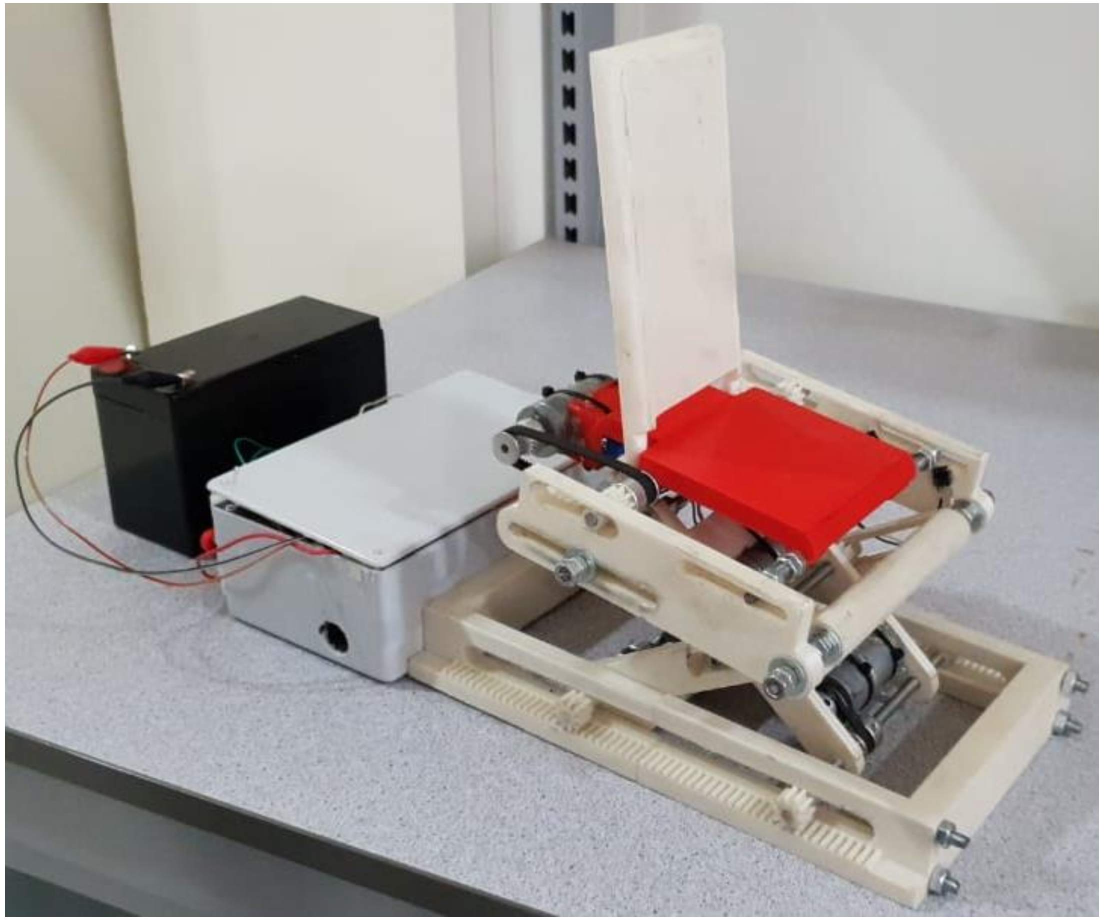
Motor Drive



Pulleys and Timing belt

CONCLUSION

Final Product



COST

PRICE LIST

	Real scale	Price	Small scale	Price
Scissor motors x2	13KN/50cm Linear actuator	$ 400	1300N/5cm Linear actuator	$ 100
Seat+ lower fixture motors x3	1200N/40cm Linear actuator	$ 150	1200N/40cm Linear actuator	$ 120
Inner scissor pin motors x2	1500N/50cm Linear actuator	$ 160	150N/5cm Linear actuator	$ 90
Movement(wheels) X2	High torque dc motors	$ 600	Dc motors	$ 60
Chassis material	Aluminum links and sheets	$ 100 - 200	Filaments for the 3d printer	$ 20 - 40
Labor for chassis work		$ 200 - 400	3D Printed	$ 0.00
Control and electrical work	Arduino Mega +relays(2 per motor) +transistors	$ 100	Arduino Mega +motor drivers(1 per 2 motors)	$ 70 - 80

TOTAL PRICE

Real scale prototype	$ 1330 - 1630
Small scale prototype	$ 470 - 500

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REFERENCES

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