ENGINEER 1C03 - Engineering Design and Graphics
Engineer 1 Gear Prosthetic Project
Instructor: Dr. Doyle

Final Project Report

Due Date: Dec. 4, 2018
Team 129
Lab Section: L02
Harkeerat Kanwal - kanwalh - 400182343
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As a future member of the engineering profession, the student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement of my understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University and the Code of Conduct of the Professional Engineers of Ontario.

Submitted by Harkeerat Kanwal, 400182343 

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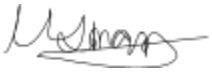
Submitted by Usman Asad, 400199934 

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Submitted by Malik Awan, 400200045 

Table of Contents

1. Introduction

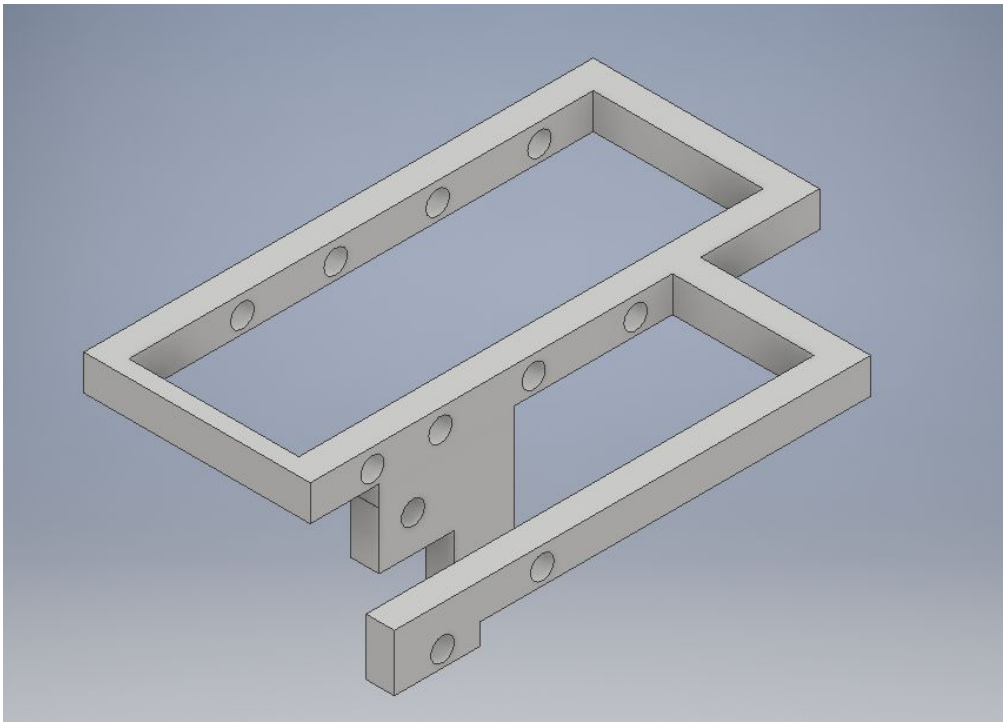
1.1 Mechanism Overview

This report shall detail the gear train mechanism made by Group 129 for the final project of this course. An input speed of 108.36 rotations per minute from a motor/hand-crank was converted into an output speed of 7.5 rotations per minute at two seperate output locations (for the forefinger and thumb) in a model hand prosthetic. A gear train consisting of 12 spur gears, meshed and axially connected, was used to accomplish this, within the given dimensional constraints.

1.2 Reaching a Solution

To calculate the number of gears required, and the number of teeth, module and diametral pitch for each gear, a mounting bracket that would fit into the hand-frame of the prosthetic was first created, see Figure 1.

Figure 1 - Mounting Bracket



With the dimensional constraints now known, and the output positions defined, we then used trial and error to calculate the numbers of teeth and modules of the gears in a train that would result in the desired total gear ratio of 14 (determined using input and output velocities). The final design we came up with and gear table can be seen in Sections 2 and 3. The way we resulted in our final design can be seen in figure 2.

Figure 2 - Gear Calculations

Input Speed = 108.36 RPM , Required Output Speed = 7.5 ± 0.375 Rpm

Required gear ratio:

- A whole number gear ratio would be easier to get and to work with

$Gr = \frac{108.36 \text{ RPM}}{7.5 \text{ RPM}}$ → Gr of 14 is a good whole number

$= 14.448$

$\text{Output Speed} = \frac{\text{input speed}}{\text{Gear Ratio}}$

$= \frac{108.36}{14}$ ✓ This value is within the marginal error range.

$= 7.74 \text{ RPM}$

- Using minimum sized gear (12) and a 24 tooth gear you can get a gear ratio of 2. Using axial connections you can increase this to a Gr of 4. After that we want the Gr to be 7, so we can double it to 14 Using a 12 tooth and 24 tooth gear later on. To get it to 7 we used a 21 tooth gear.

Gear Calculations from A to 14

$Gr = \frac{24}{12} \cdot \frac{24}{12} \cdot \frac{21}{12} \cdot \frac{12}{12}$

$Gr = 7$

- Now that we have a gear ratio of 7, using an axial connection from the last 12 gear, we can have movement on the other end of the bracket. All that needs to be done is Double the Gr. A spacer gear is used for the thumb so that it spins in a different direction than the finger.

Finger

$Gr = 7 \cdot \frac{24}{12}$

$= 14$

$Wout = \frac{108.36}{14}$

$= 7.74 \text{ RPM}$

Thumb

$Gr = 7 \cdot \frac{12}{12} \cdot \frac{24}{12}$

$= 14$

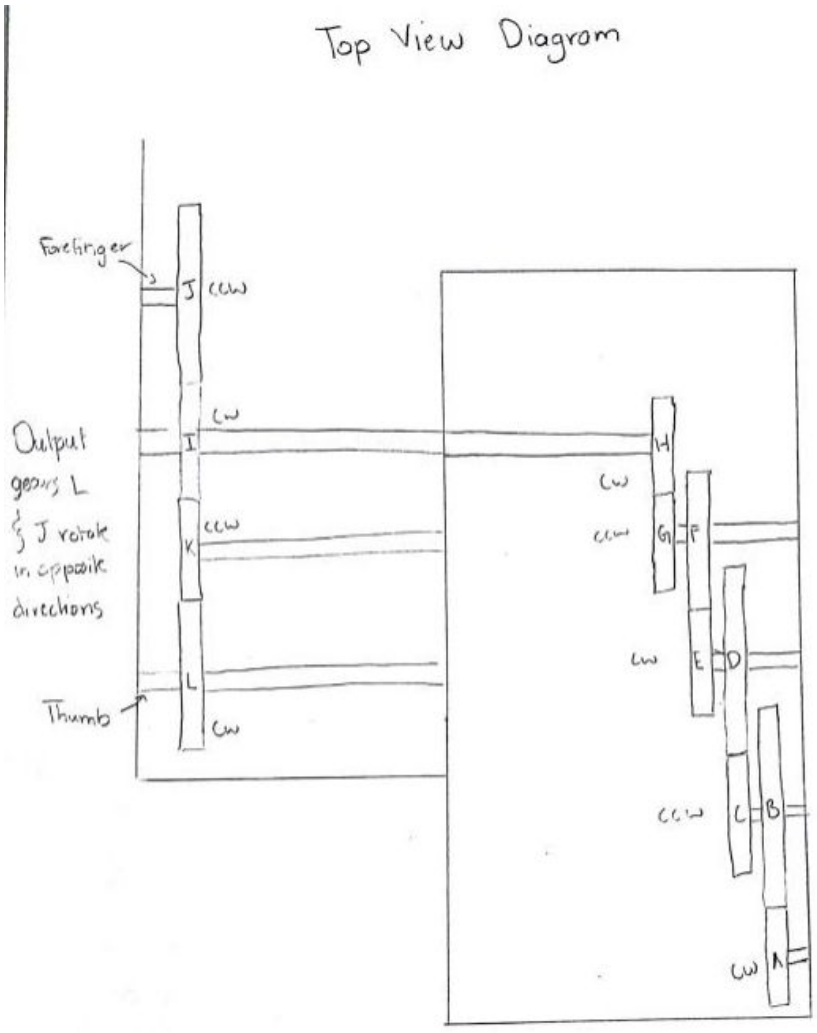
$Wout = \frac{108.36}{14}$

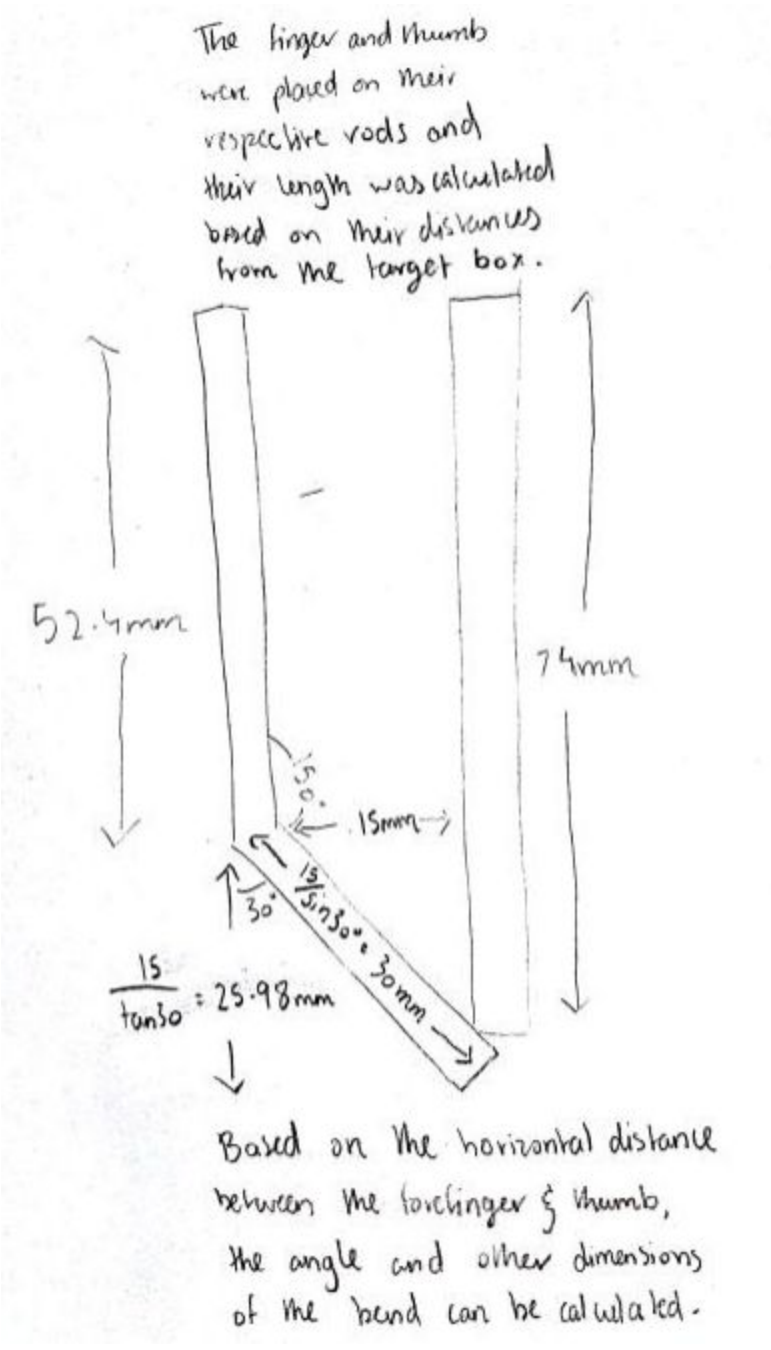
$= 7.74 \text{ RPM}$

2. Gear Train Diagram

Figure 3 depicts the top view of the gear train.

Figure 3 - Gear Train Diagram and Finger Diagram





3. Gear Table

Table 1 displays the attributes of the gears used in the gear train. Gears with matching colours are meshed to each other. A change in colour indicates an axial connection with the previous gear. Gear I is meshed with both gears J and K but gear L is only meshed with gear K. Please refer to the gear train diagram in Section 2 for clarification.

Table 1 - Gear Attributes

Gear Name	Type of Gear	Pitch Diameter(mm), D	Module (mm/tooth), m	Number of Teeth, z
A	Spur	12	1	12
B	Spur	24	1	24
C	Spur	12	1	12
D	Spur	24	1	24
E	Spur	12	1	12
F	Spur	21	1	21
G	Spur	12	1	12
H	Spur	12	1	12
I	Spur	12	1	12
J	Spur	24	1	24
K	Spur	13	1	13
L	Spur	24	1	24

4. Assembled Prototype

Figures 4 and 5 are snapshots of the finished assembly in Inventor and figure 5 shows the 3D printed and assembled prototype.

Figure 4 - Mounting Bracket Assembly

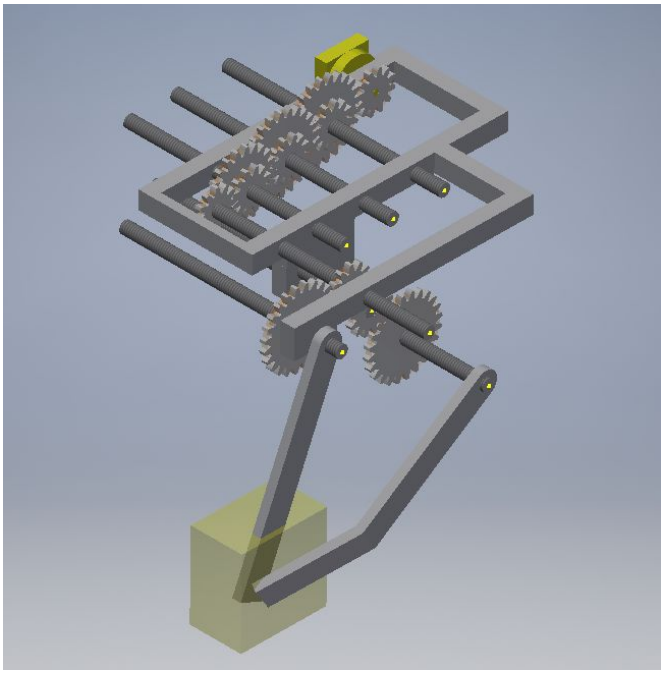


Figure 5 - Assembly With Hand-Frame

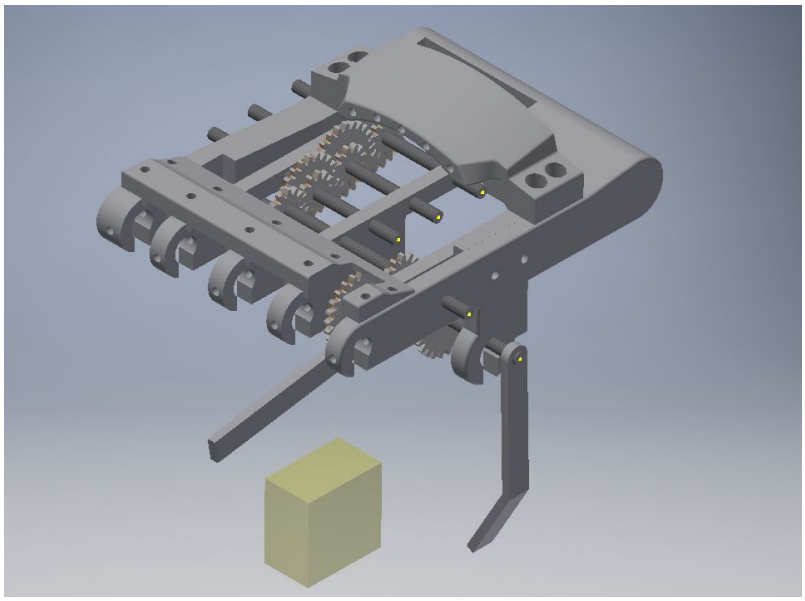
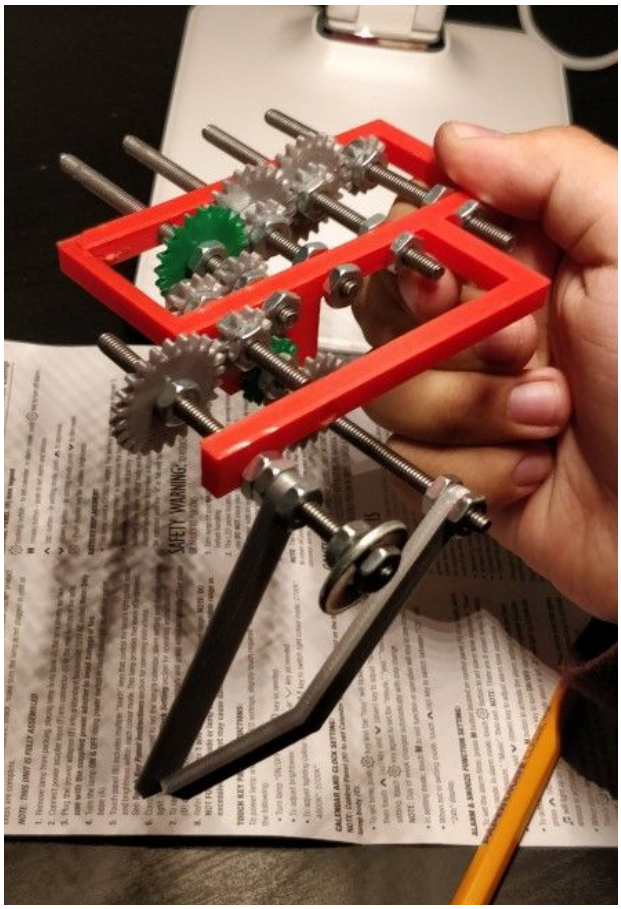


Figure 6 - 3D Printed Assembly



5. Dynamic Simulation and Probe Graphs

A video of the dynamic simulation can be seen at:
https://drive.google.com/file/d/1i28uODFyJDztGEO4XS2-UCckIAzoOD6Q/view?usp=sharing

The probe graphs can be found in Figures 7 and 8, along with the input graph in Figure 9 following with a chart of all the data:

Figure 7 - Index Finger Probe Vs Time Graph

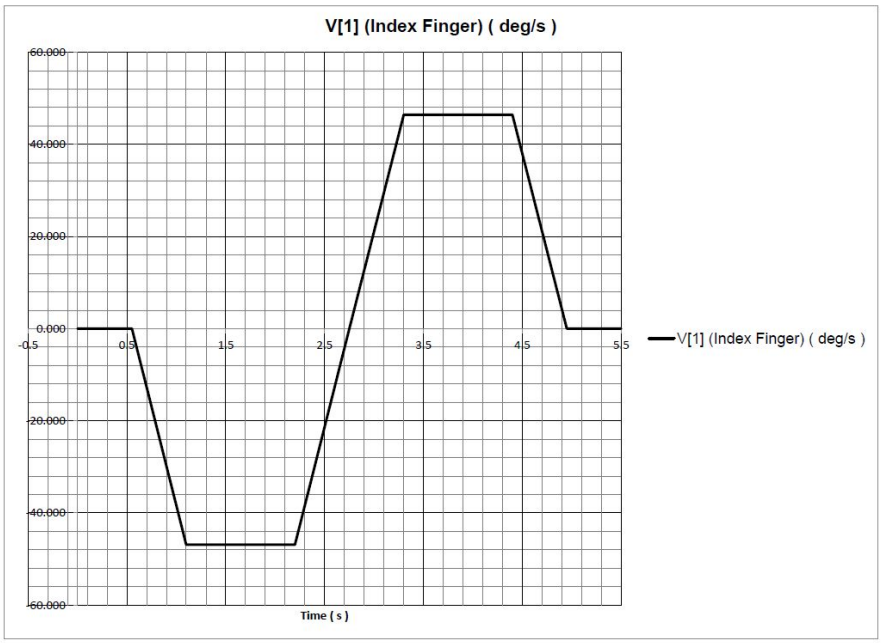


Figure 8 - Thumb Probe Vs Time Graph

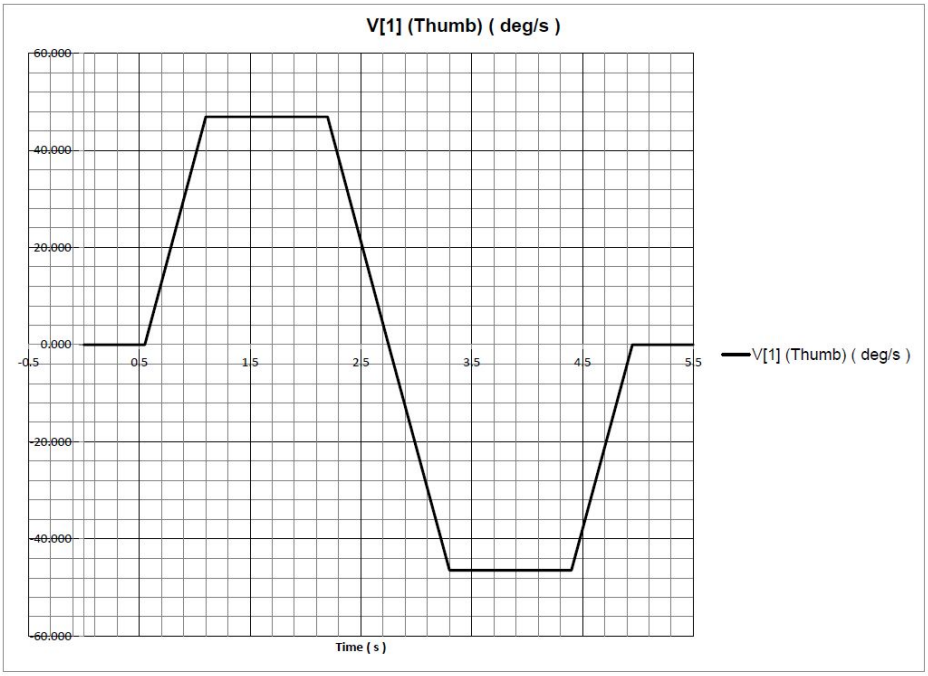


Figure 9 - Input Speed Vs Time Graph

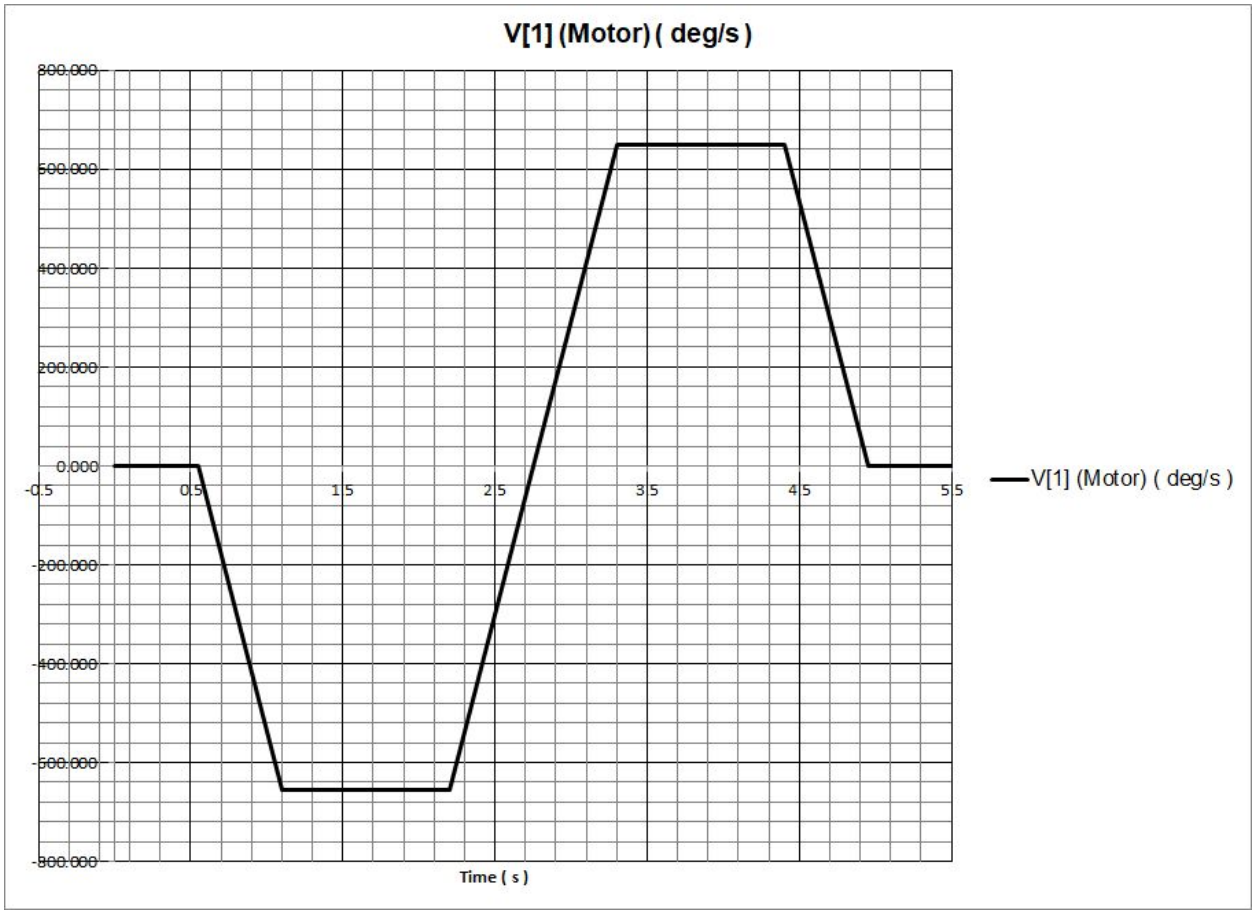


Figure 10 - Input Speed vs Time Chart

Time (s)	V[1] (Motor) (deg/s)	V[1] (Index Finger) (deg/s)	V[1] (Thumb) (deg/s)
0.00000	0.00000	0.00000	0.00000
0.55000	0.00000	0.00000	0.00000
1.10000	-656.46900	-46.88840	46.89060
1.65000	-656.46900	-46.88840	46.89060
2.20000	-656.46900	-46.88840	46.89060
2.75000	0.00000	0.00000	0.00000
3.30000	650.16000	46.43770	-46.44000
3.85000	650.16000	46.43770	-46.44000
4.40000	650.16000	46.43770	-46.44000
4.95000	0.00000	0.00000	0.00000
5.50000	0.00000	0.00000	0.00000

6. Engineering Drawings

Figures A to N show the engineering drawings of gears A to L, as well as both fingers. An engineering drawing of the final assembly follows along with an exploded view of the assembly, shown in Figure. Pitch diameters for the gears can be gleaned from the table in Section 3.

Figure A

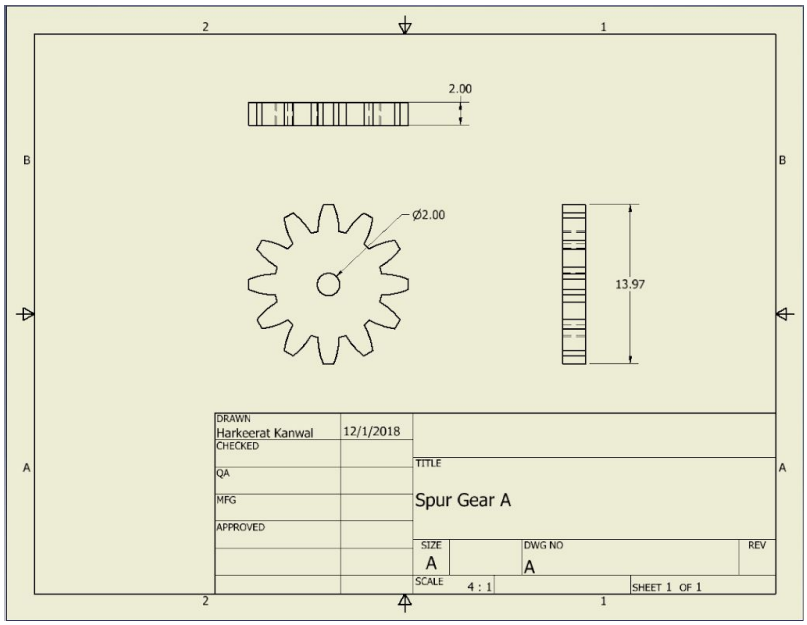


Figure B

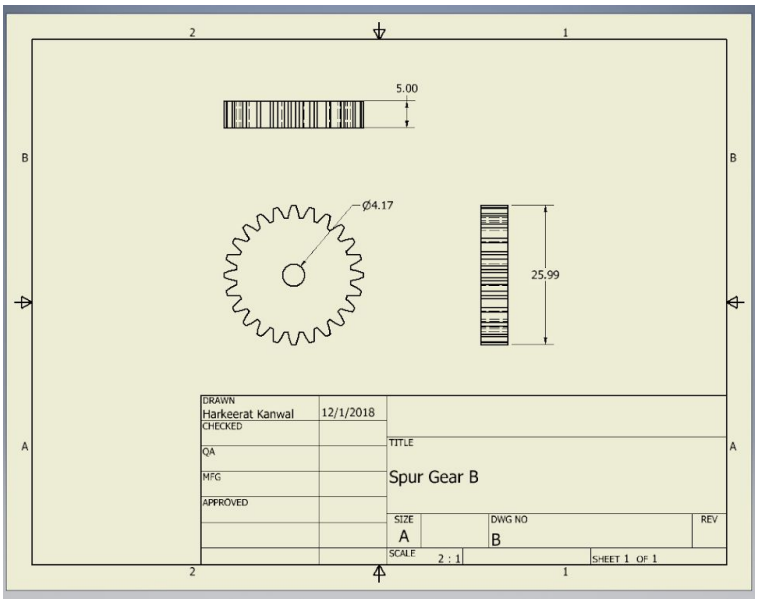


Figure C

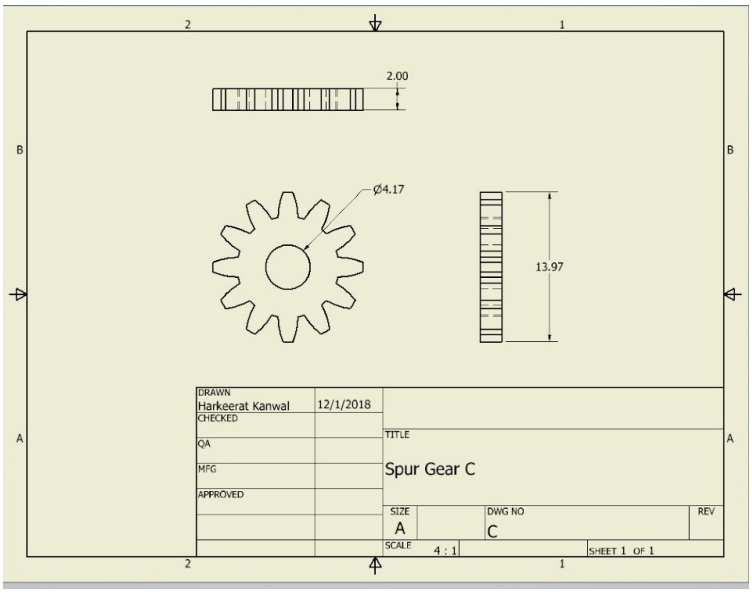


Figure D

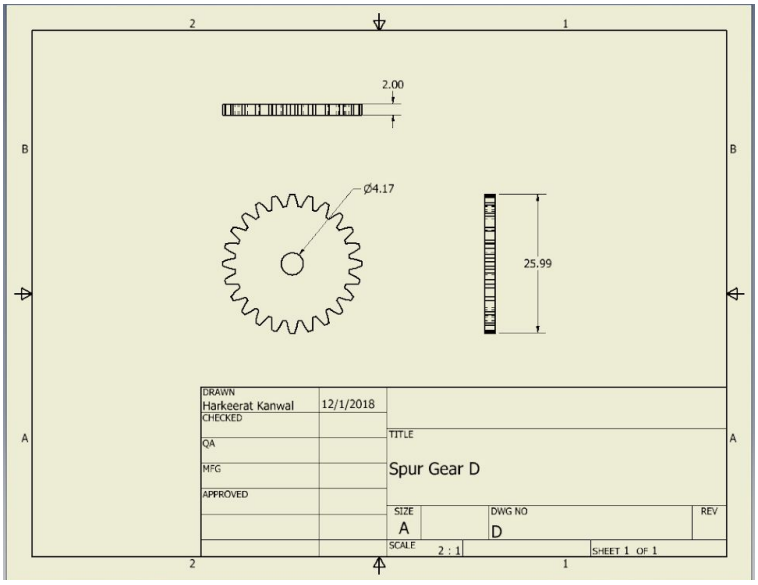


Figure E

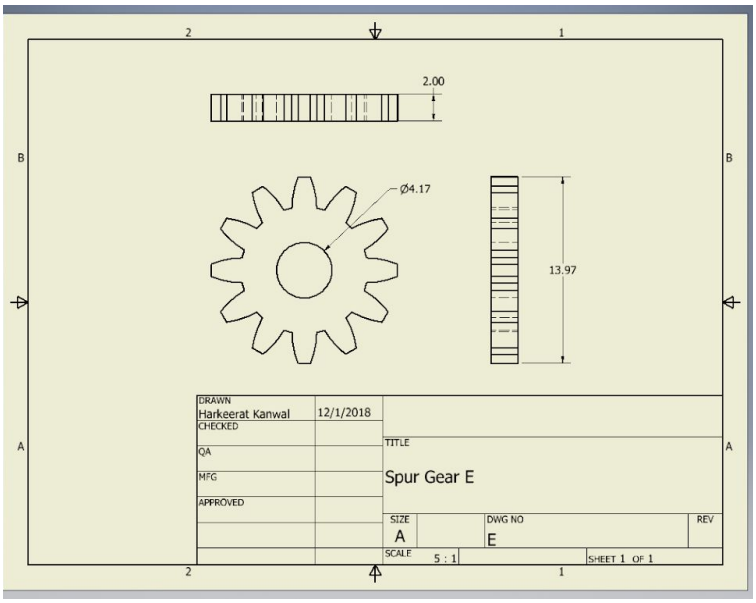

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Figure F

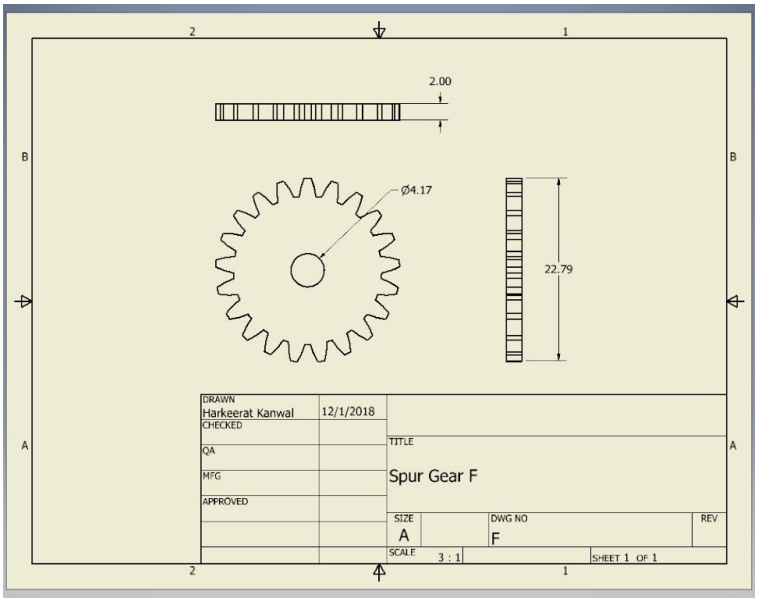
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Figure G

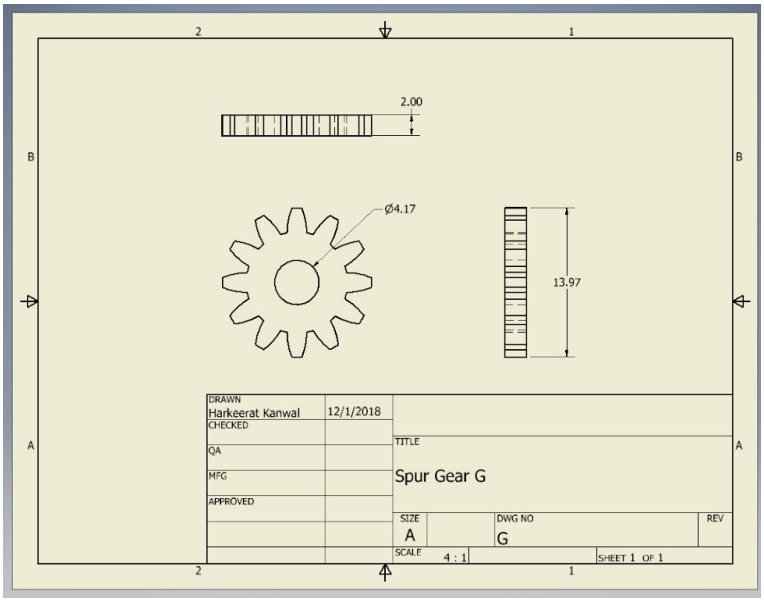


Figure H

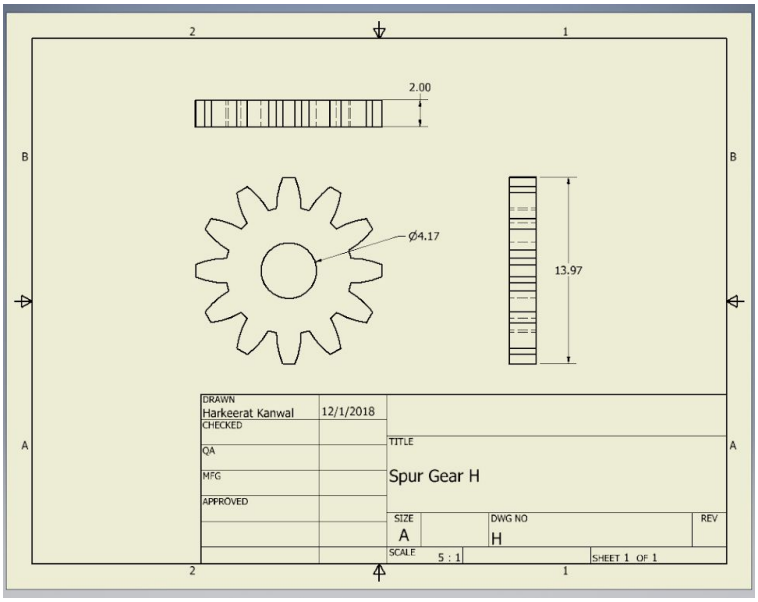


Figure I

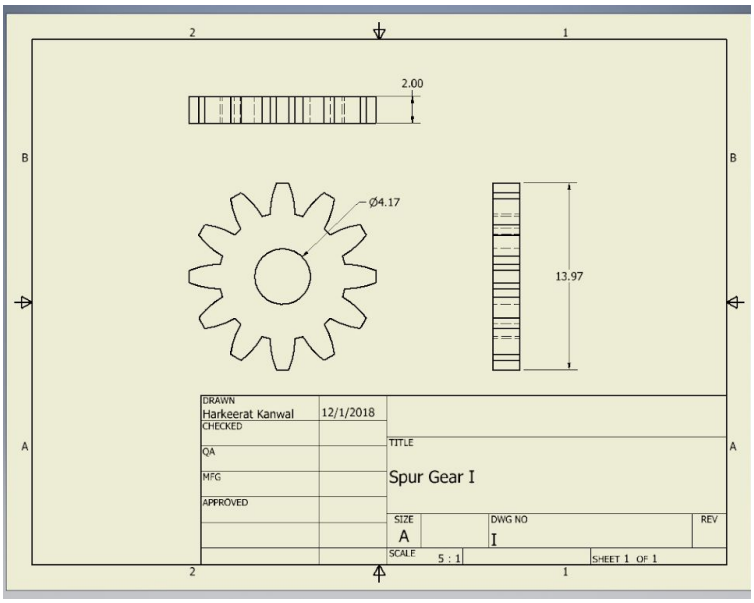


Figure J

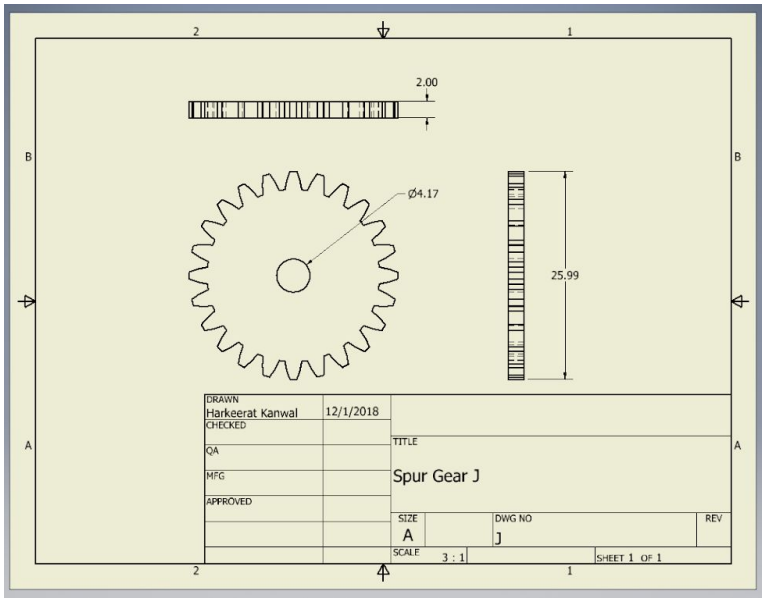


Figure K

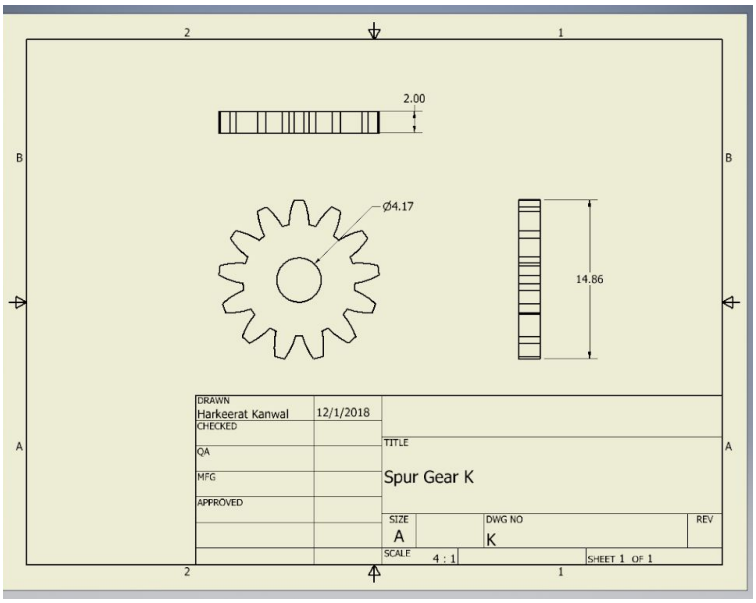


Figure L

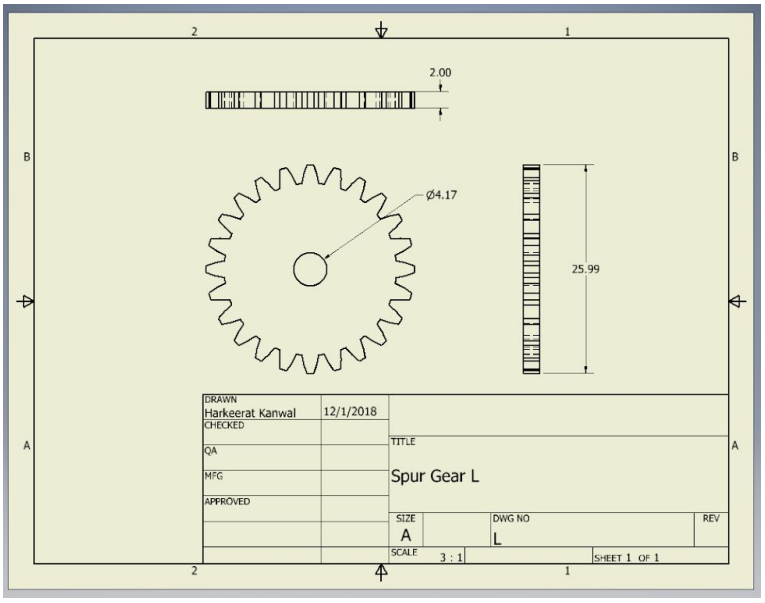


Figure M

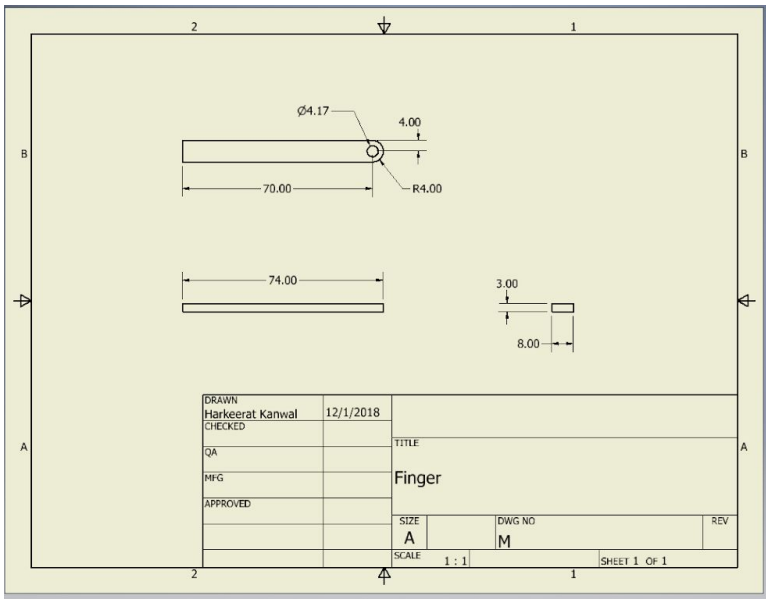


Figure N

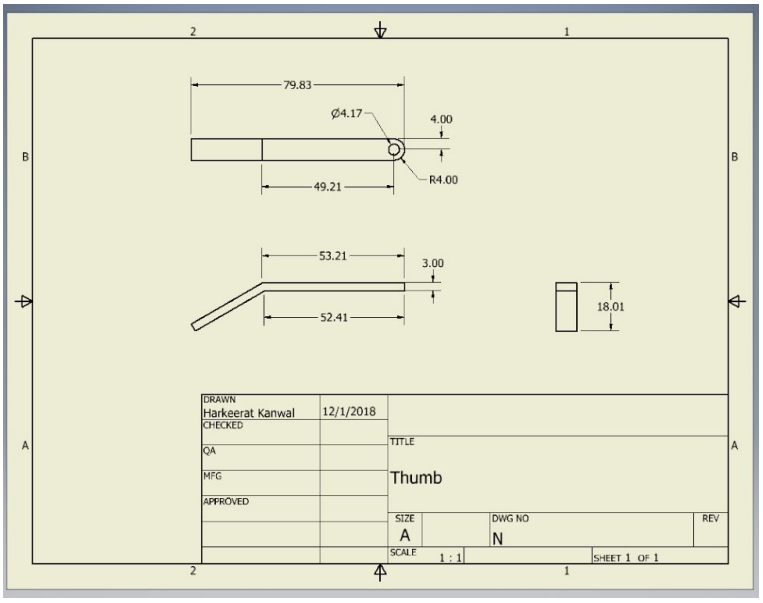
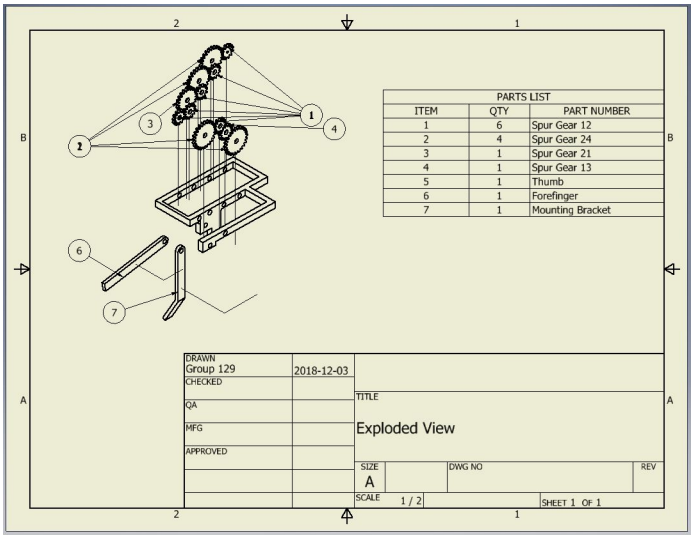


Figure O



7. Group Participation

7.1 Work Contribution

Harkeerat Kanwal	- Report writing for milestones and final report - Engineerings drawings - Help with gear calculations
Usman Asad	- Report writing for milestones and final report - Worked on CAD design - Assembled printed model - Help with gear calculations - 3D printed gears and mounting bracket
Malik Awan	- Report writing for milestones and final report - Worked on CAD design - CAD simulation and animation - Exploded view engineering drawing - Help with gear calculations - 3D printed gears and mounting bracket

7.2 Meeting Attendance

Meetings were held every week on Monday around 7pm (timings were flexible based on circumstances), in addition to informal meetings online over the weekends.

	October 2018				November 2018				December 2018
Tasks	8	15	22	29	5	12	19	26	3
Select teams									
Milestone 0									
Preliminary Design (Milestone 1)									
3D printing components (Milestone 2)									
Inventor design and simulation									
Final Report (Milestone 3)									
Peer Review									
Group Meetings									

7.3 Team Meetings and Responsibilities

Date	**Purpose of Meeting**
October 22, 2018 Everyone attended	-Worked on Preliminary design
October 29, 2018 Usman and Malik attended	-3D printed gears
November 5, 2018 Usman and Malik attended	-3D printed mounting bracket
November 12, 2018 Everyone attended	-Completed milestone 0
November 19, 2018	-Worked on inventor design and simulation
November 26, 2018 Everyone attended	-Finished inventor design and simulation -Worked on Final Report
December 3, 2018 Everyone attended	-Finished Peer Review -Finished Final Report

8. Bibliography

[1] Licharowicz, *YouTube*, 29-Mar-2017. [Online]. Available: https://www.youtube.com/watch?v=TKAAgSzZyo0. [Accessed: 03-Dec-2018].

[2] *YouTube*, 21-Oct-2013. [Online]. Available: https://youtu.be/BhiaJjekmfA. [Accessed: 03-Dec-2018].

[3] G. Turner, "Simple Gear Ratio Explained," *Sciencing.com*, 24-Apr-2017. [Online]. Available: https://sciencing.com/simple-gear-ratio-explained-6651403.html. [Accessed: 03-Dec-2018].

[4] "Autodesk Inventor." Autodesk, San Rafael, 2017.