FINAL REPORT

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Introduction:

Project Statement:

we are required to design and build a mechanism that can:

- lift 5 blocks of wood (each 40mm by 40 mm by 120 mm)

to a table level of 70 cm, then

- transport them across the table a distance of 50 cm.

In other words, we are required to fulfill a lifting mechanism as well as a translational one, considering speed, weight, and cost, along with other constraints to be discussed.

Team Members:

- Ray Abou Moussa
- Chirine Khazaal
- Yara Diab
- Sara Alawieh

The Machine's Principle:

Considering that speed played a huge role in this project, we aimed for fulfilling the task with a minimal time. For this, we choose a mechanism that can do both operations with no return, not even a quick one.

The two mechanisms we have chosen are connected, so we will begin with how each function individually.

a. The lifting mechanism consists of a rubber belt to be connected to two Plexiglass shafts, one at the ground level and the second slightly above the table level (70cm). This belt is connected to the shafts using bearings fixed on the shaft to reduce slipping and allow smooth belt rotation. The bottom shaft will be held using a 20cm support that will fix the entire mechanism in place and hold the shaft in place, whereas the upper shaft will be held by two Plexiglass supports that will ensure the belt is fully stretched by the shafts. The upper shaft will also have a customized gear on it to link the lifting mechanism to the translational one. The belt will also hold 5 wooden plates, fixed horizontally as they climb up the belt and hold the boxes to be lifted.

b. The second mechanism holds the function of pushing, or sliding the boxes 50 cm along the table. The mechanism works somewhat like the lifting one, but it is placed in a horizontal position instead. It is placed at a distance above the table, held by two supports, and consists of a rotating belt that has small plates, enough to provide contact with the boxes underneath the mechanism and push them one after the other. The belt, as it rotates, uses the small plates to first push the boxes as they reach the table level, to the table itself, before the translating mechanism begins. The belt is also stretched by two Plexiglass shafts that hold bearings on which the rubber belt will rotate.

Figure 1 Picture of the Assembled Mechanism

Challenges:

We faced several challenges in developing this system, both in its construction, as well as in time synchronization between the two mechanisms:

i. ensuring that the lifting mechanism remains fixed vertically and doesn't fall or break loose when some values of torques at the nobs are applied.
ii. deciding on which gear radii to use to fasten up our mechanism for it to be fast.
iii. making sure that the horizontal plates doesn't interfere with the vertical plates and thus adjusting the shape of both to run smoothly without conflict. (Figure 3)
iv. adjusting the gear sizes as to allow both mechanism to rotate without having one bumping into the other.
v. holding the belts in place and not having them slip on the plexi shafts or jump of their gears.

The most difficult task here requires we produce a close-to-perfect time synchronization phenomenon between the two mechanisms. For that, we decided to make the whole mechanism rotate using only one knob as to avoid having two people rotating two different knobs with different speeds and thus disturbing the time synchronous between both.

The importance of Time synchronous was that the vertical mechanism has 5 wooden shelves connected at some distances, and the boxes on these shelves will at some point each reach the second mechanism's level. As soon as this time is reached, we require small wooden planks on the second mechanism to merely push the box from each plate to the table to slide it along the table. If the time isn't purely synchronous, we will face the problem of wooden planks hitting the wooden shelves, thus causing breakage and failure of the entire mechanism.

Future Steps:

- Empty all the 30-mm diameter plexi shafts from the inside to maintain the least weight possible.
- Put two constraints on each side of the gears on which the belt will rotate to hold it in place.
- Using previous calculations, and relying on trial and error, adjust the position of the plates on the belts to maintain synchronous.
- Keep the belt in tension but not too stretched as to allow the gears to rotate.
- Adjust the knob that rotates the mechanism to reduce the volume to not more than 25 cm^3

Rough Hand Sketches

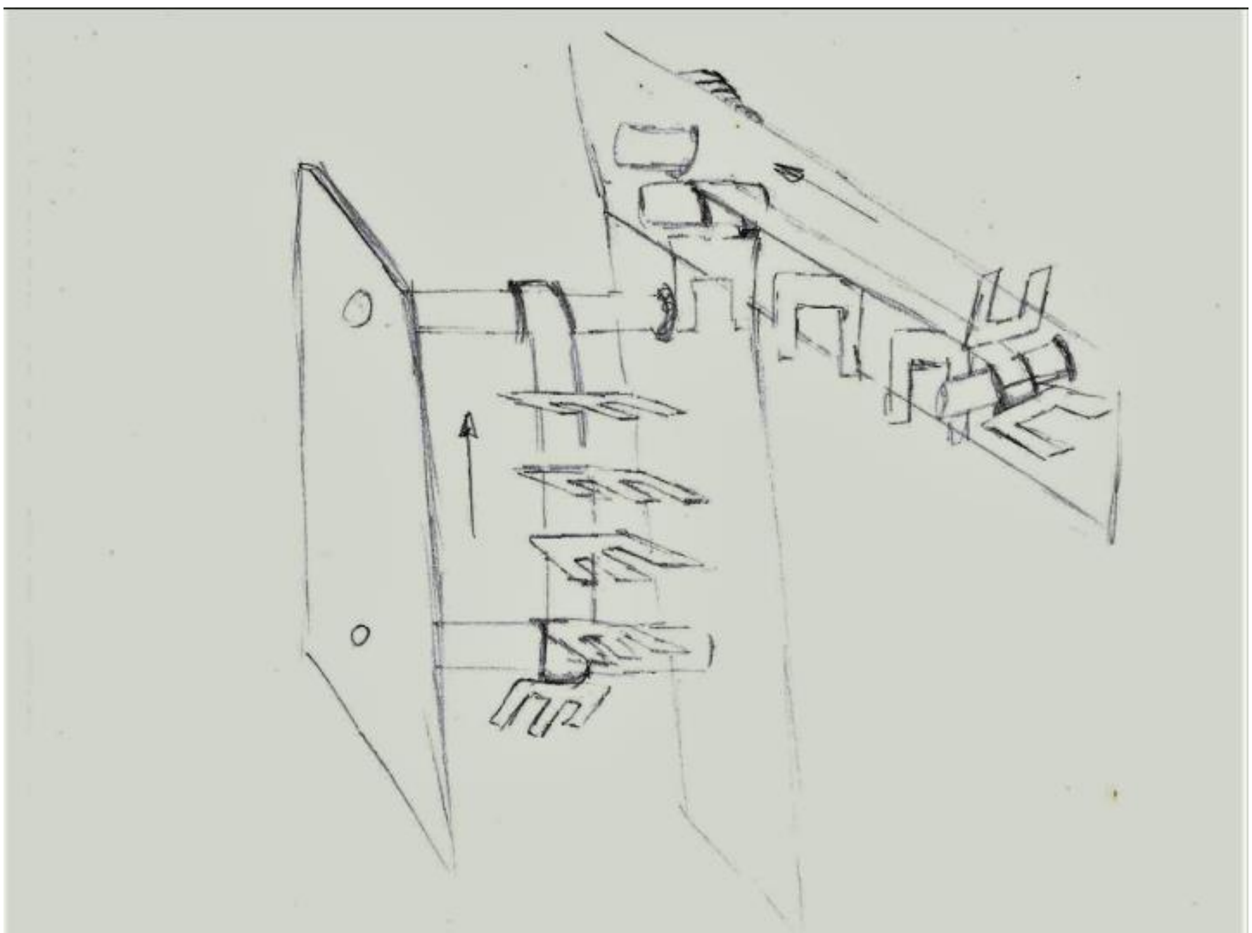

Figure 2 Over All Mechanism Idea

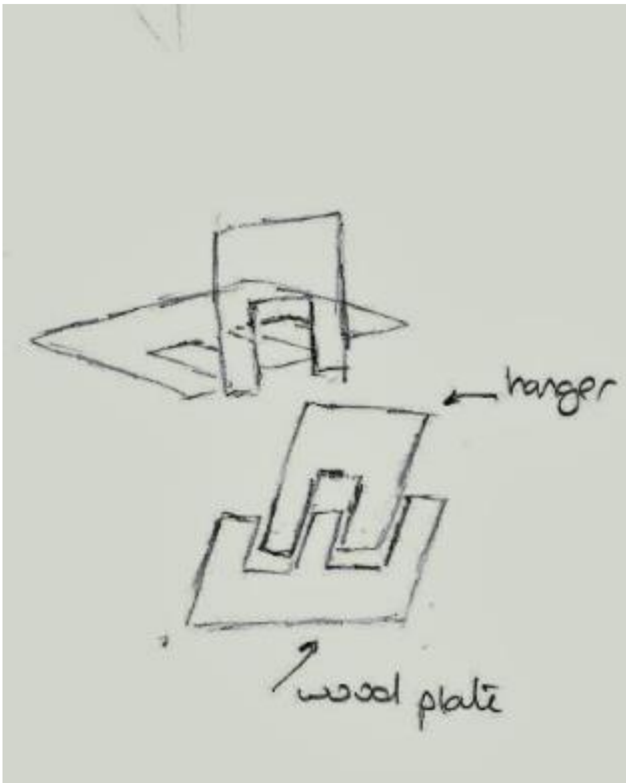

Figure 3 Hanger and Plate

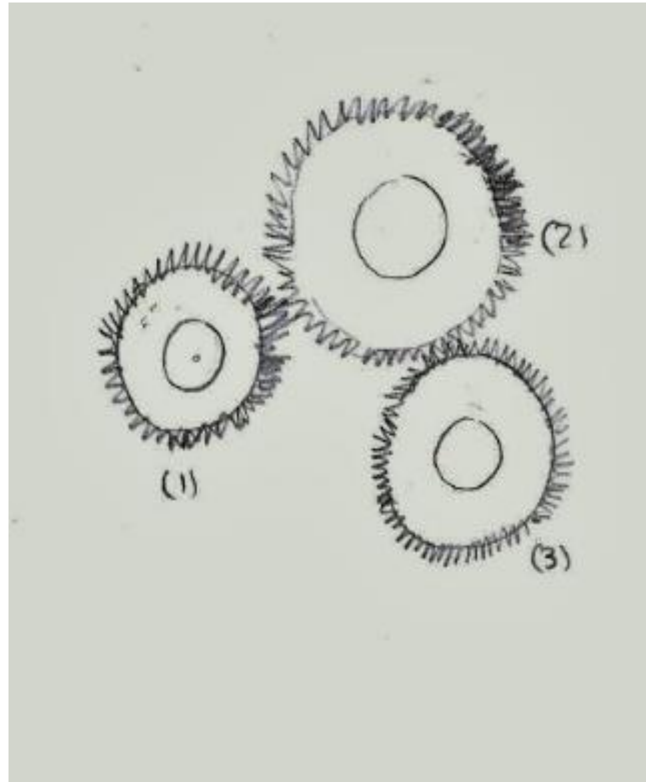

Figure 4 Gears

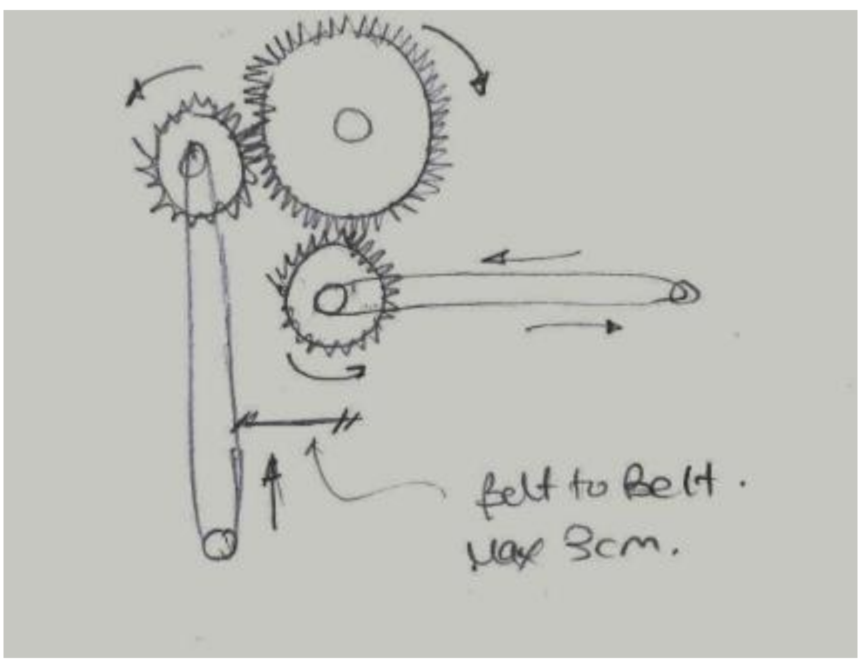

Figure 5 Rotation of Mechanism

SolidWorks Drawings

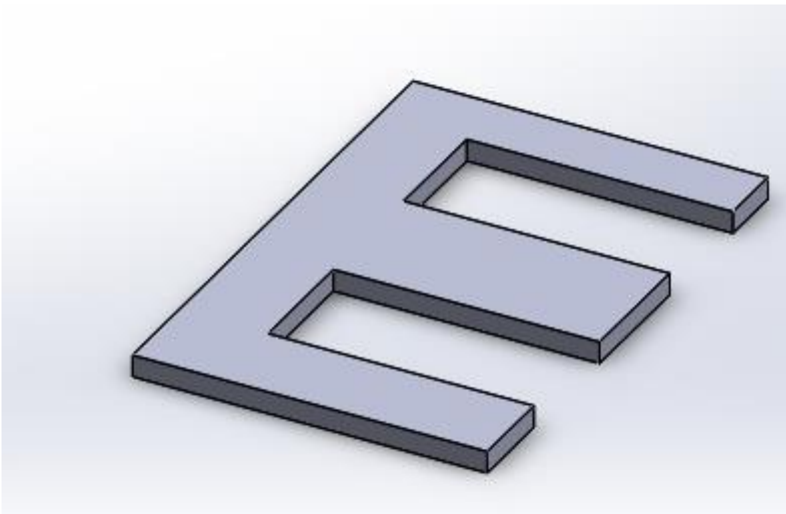

Figure 6 Wood Plate

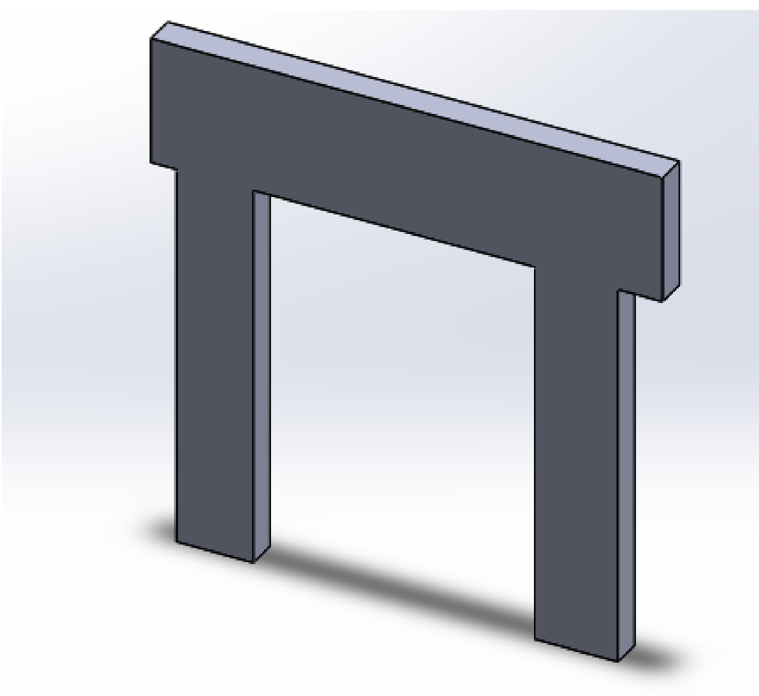

Figure 7 Hanger

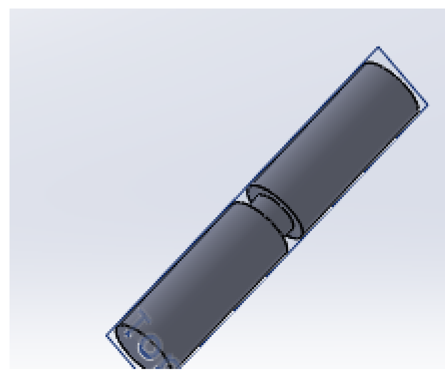

Figure8 Shaft with Groove

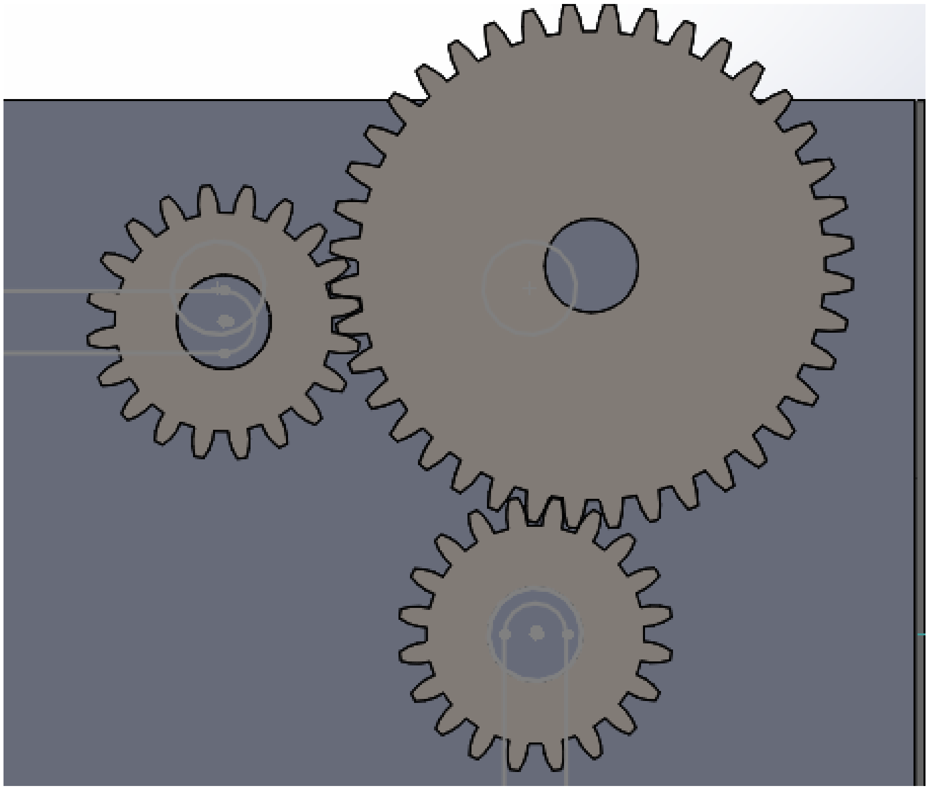

Figure 9 Meshed Spur Gears

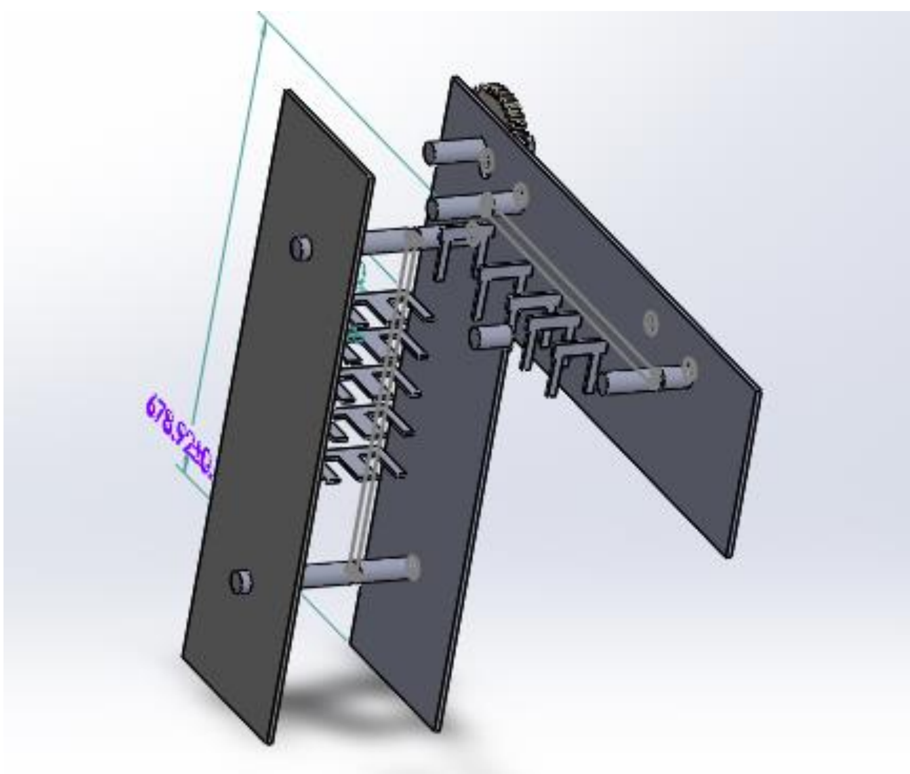

Figure 10 Assembly

Gears: Kinematic Analysis and Selection

Considering that gears were a main concern in the mechanism, we will focus the analysis on the gears and gear selections.[1]

The types of gears used are spurred gears made from Plexi glass of 15 mm thickness.

Three main gears where moving the mechanism, two gears of 70 mm outer diameter and one gear of 140 mm outer diameter. All have the same inner diameter that is 30 mm.

Calculating the diametrical pitch Pd:

Pd should be the same for both gears since they are mating.

$$Pd = \frac{N}{d} = \frac{20}{6.1644} = \frac{40}{12.3288} = 3.244\ mm$$

Calculating the Circular Pitch:

$P = \frac{\pi}{Pd} = \frac{\pi}{0.2857} = 0.968$

Calculating Base Circle Diameter:

$db_1 = d\cos\emptyset = 6.1644\text{x}\cos 20 = 5.9726$ mm

$db_2 = d\cos\emptyset = 12.3288\text{x}\cos 20 = 11.5852$ mm

Calculating Addendum:[2]

$a = \frac{1}{Pd} = \frac{1}{3.244} = 0.308\ mm$

Calculating Addendum Diameter:

$d_{a1} = d + 2a = 6.1644 + 2\text{x}0.308 = 6.7804$

$d_{a2} = d + 2a = 12.3288 + 2\text{x}0.308 = 12.9448$

Calculating Dedendum Diameter:

$b = \frac{1.25}{Pd} = \frac{1.25}{3.224} = 0.3877$

TABLE 10.3 AGMA Full-Depth Gear Tooth Specifications

Tooth Feature Pressure angle, ϕ	Coarse Pitch ($P_d < 20$) $14\frac{1}{2}°$ or 20° or 25°	Fine Pitch ($P_d \geq 20$) 20°
Addendum, a	$\frac{1.000}{P_d}$	$\frac{1.000}{P_d}$
Dedendum, b	$\frac{1.250}{P_d}$	$0.002 + \frac{1.2}{P_d}$
Working depth, h_k	$\frac{2.000}{P_d}$	$\frac{2.000}{P_d}$
Whole depth, h_t	$\frac{2.250}{P_d}$	$0.002 + \frac{2.200}{P_d}$
Circular tooth thickness, t	$\frac{1.571}{P_d}$	$\frac{1.571}{P_d}$
Fillet radius, r_f	$\frac{0.300}{P_d}$	not standardized
Min. clearance, c	$\frac{0.250}{P_d}$	$0.002 + \frac{0.200}{P_d}$
Clearance (ground tooth), c	$\frac{0.350}{P_d}$	$0.002 + \frac{0.350}{P_d}$
Min top land width	$\frac{0.250}{P_d}$	not standardized
AGMA standard	201.02	207.04
Face width	$\frac{12}{P_d}$	$\frac{12}{P_d}$

[1] Note that Gear One and Three are identical so our analysis will be focused only on Gears One and two.
[2] Using table 10.3 from the book

Clearance:

C = $\frac{0.25}{Pd} = \frac{0.25}{3.244} = 0.0775$

For Gears in Mesh:

Center Distance:

C = $\frac{(N_1+N_2)}{2Pd} = \frac{(20+40)}{2x3.244} = 9.2478\,mm$

Contact Ratio:

i.e.: average number of teeth that are in contact at any instant

mp=$\frac{Z}{Pb}$

Pb=$\frac{\pi d_1 cos\emptyset}{N_1} = \frac{\pi d_2 cos\emptyset}{N_2} = \frac{\pi x 6.1644 x cos20}{20} = 0.909\,mm$

Z=$\sqrt{(r_2+a)^2-(r_2cos\emptyset)^2} - r_2 sin\emptyset + \sqrt{(r_1+a)^2-(r_1cos\emptyset)^2} - r_1 sin\emptyset = 1.486$

Mp=$\frac{1.486}{0.909} = 1.635$

This range is acceptable since large values are desirable.

While one pair of teeth are always in contact, the other are 63% of the time in contact.

Kinematics

For the gear train used in our project, notice that the middle gear mates with the small gear and forms the first ratio, and the middle gear also mates with the other small gear and forms the second ratio.

TV= $\frac{-d_2}{d_1} x \frac{-d_3}{d_2} = 1$

VR= $\frac{w_1}{w_2} = \frac{r_2}{r_1} = 2$ so w_2= 2xw_1

$w_1 = \frac{v_1}{r_1} = \frac{\frac{\Delta R}{t}}{r_1} = \frac{\frac{0.5}{18}}{0.07} = 0.396\,rd/s$ this gives w_2= 2x (0.396)=0.7936 rd/s

The Idle here was used to reverse the direction of the output. It was sized conveniently to locate the centers of the input and output gears to maintain time synchronous.

Costs

Items	Cost per Item	Quantity	Total Charge
Plexi gears, 70 mm dia	7$	x2	14$
Plexi gears, 140 mm dia	12$	X1	12$
Plexi gears, 60 mm dia	1$	X8	8$
Belts (56 cm)	3.5$	X2	7$
Wood plates 80x120x5	0.2$	X10	2$
Wood plates 900x20x5	1.5$	X3	4.5$
25 cm Plexi shaft 30 mm dia	3$	X2	6$
16 cm Plexi shaft 30 mm dia	1.5$	X3	4.5$
Bearings Inner= 30 mm Outer= 55 mm	3$	X7	21$
Entire Project	-	-	79$

Appendix A Gear CAD drawings

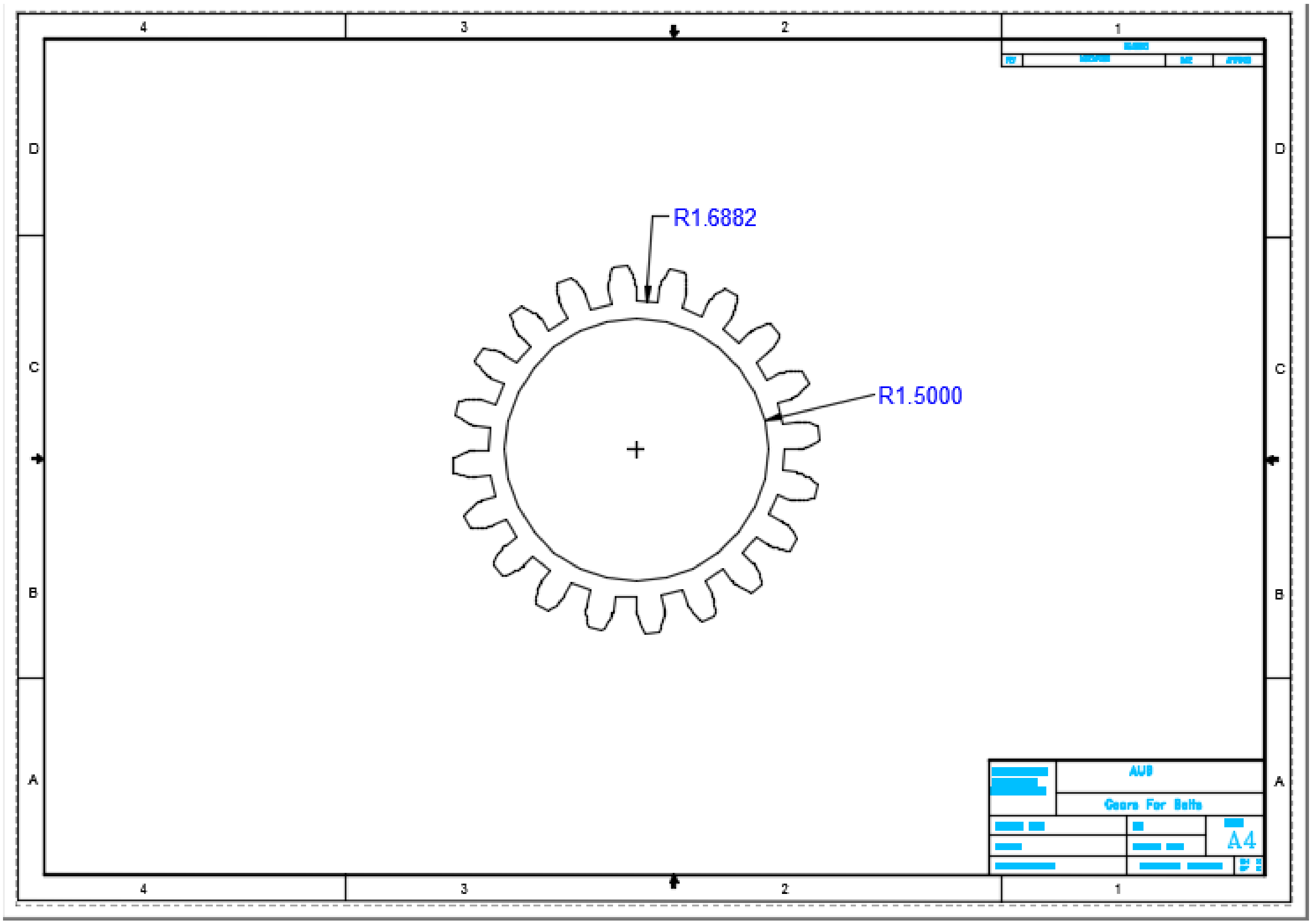

Figure 11 Gear for Belt

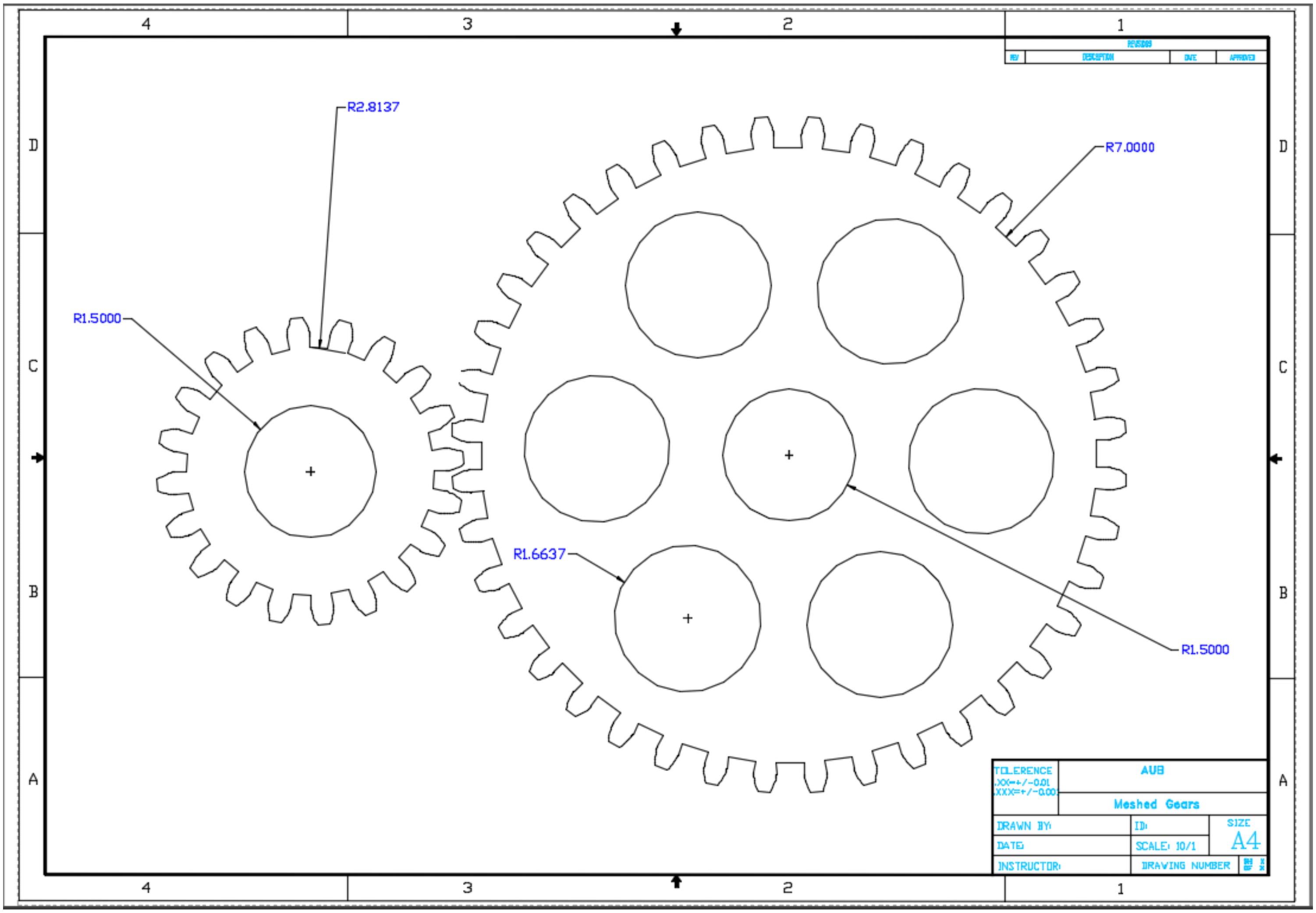

Figure 12 Meshed Spur Gears