TA212 : MANUFACTURING PROCESS-II

SEMESTER 2024-25-II

Group No. 35

METAL DETECTOR CAR






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Course Instructor : Dr. Arvind Kumar

Tutor : Mr. Sushil Kumar

Guide : Mr. G P Chaturvedi

CONTENT

S. No.	Component Name	Quantity	Dimensions (mm)	Material Used	Process
1	Base Plate	1	300 x 120	Mild steel	Drilling, Cutting
2	Wheel(R35)	4	8.00 Ø , 70.00 Ø, 10.00	Plastic	3D Printing
3	Steering wheel support	2	80 x 38 x 68	Plastic	3D Printing
4	Steering wheel support	2	80 x 38 x 68	Plastic	3D Printing
5	Front U shaped rod	1	120 x 35 x 15	Mild steel	Drilling, Cutting
6	Steering connector	1	120 x 15 x 15	Mild steel	Drilling, Cutting
7	Last steering support	1	120 x 15 x 15	Mild steel	Drilling, Cutting
8	Main bolt support	1	65 x 25 x 40	Mild steel	Drilling, Cutting
9	Main bolt holder	1	6.00 Ø , 25.00 Ø	Plastic	3D Printing
10	Main bolt	1	M12*1.5 100	Mild steel	NIL
11	Spur Gear1	1	M1.5, 40T, 60 Ø	Mild steel	Milling, Turning
12	Spur gear 2	1	M1.5, 40T, 60 Ø	Mild steel	Milling, Turning
13	L support	1	50 x 50	Mild steel	Drilling, Cutting
14	Main Shaft	1	10.00 Ø , 204	Mild steel	Turning
15	Back motor supporter	1	190 x 100	Mild steel	Drilling, Cutting
16	Front motor holder	1	90 x 45 x 50	Mild steel	Drilling, Cutting
17	Motor	2	Standard	Standard	NIL
18	Metal Detector	1	Standard	Standard	NIL

PROJECT OVERVIEW

Project Overview :

This project aims to develop a **metal detector-mounted toy car** that can autonomously or manually navigate an area while detecting metallic objects. The system integrates an **Arduino microcontroller**, a **metal detector module**, and **DC motors** to create a functional prototype. The metal detector will continuously scan the ground, and upon detecting a metallic object, the system will trigger an alert (such as a buzzer or LED). The toy car will be powered by a battery and controlled either manually (via remote control) or autonomously using sensors and programmed logic.

KEY OBJECTIVES :

1) Metal Detection Capability – Accurately detect various types of metals (ferrous and non-ferrous) within a specified range.

2) Integrate the metal detector with an Arduino-based toy car for mobility.

3) Provide an alert mechanism (such as a buzzer or LED) when metal is detected.

4) Design a compact and cost-effective prototype that demonstrates real-world metal detection applications.

Acknowledgement

We would like to express our sincere gratitude to everyone who supported and guided us throughout the development of our group project, ***Metal Detector Car*.**

We thank **Mr. Sushil Kumar**, our **Tutor**, for reviewing our progress during the mid-term evaluation and for asking thoughtful questions that helped us reflect on our approach and improve our direction.

Our special thanks to **Mr. G P Chaturvedi**, our **Project Guide**, for his consistent support and technical guidance. His valuable feedback played a key role in shaping the design, automation, and mechanical aspects of our project.

We are also grateful to **Dr. Arvind Kumar**, our **Course Instructor**, for providing us with this opportunity and for his academic guidance throughout the project duration.

Lastly, we would like to acknowledge the efforts and collaboration of every team member, whose active participation and coordination made this project a truly enriching and successful experience

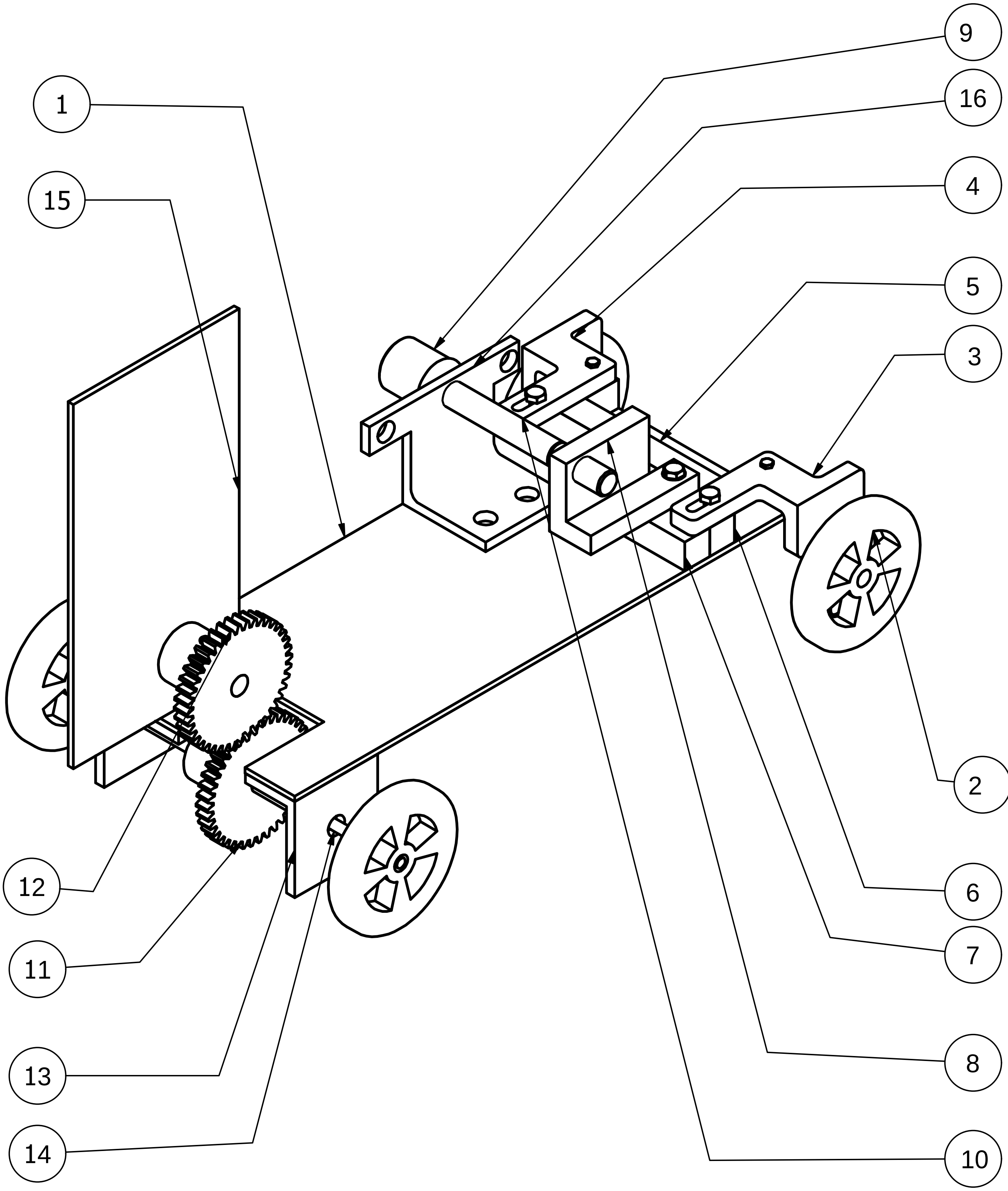
Abstract

This project presents the design and implementation of an Arduino-controlled metal detector car that autonomously navigates and detects metallic objects. Aimed at enhancing the automation and efficiency of metal detection in various environments, the system integrates an Arduino-based control unit to drive the car and process inputs from the metal detection sensor. The car is capable of moving across surfaces while continuously scanning for metal objects beneath it. By integrating DC motors, sensors, and a user-friendly control interface, the system ensures precise detection and responsive movement. The project explores key concepts in mechanical design, embedded systems, and sensor integration, with the goal of developing a functional and intelligent mobile detection unit.

Motivation

In an era where automation and intelligent systems are revolutionizing routine tasks, the development of a metal detector car serves as a practical and educational demonstration of embedded system applications. Our motivation behind this project was to explore how basic mechanical and electronic components could be integrated to design a system capable of detecting hidden metallic objects while being mobile and autonomous.

Metal detection has wide-ranging applications—from security and industrial inspections to archaeology and mine detection. By leveraging Arduino and motor-controlled movement, we aimed to create a compact, cost-effective, and efficient solution that not only automates the detection process but also enhances accessibility and functionality. This project allowed us to bridge theoretical knowledge with real-world implementation, fostering innovation through hands-on learning in electronics, robotics, and automation.



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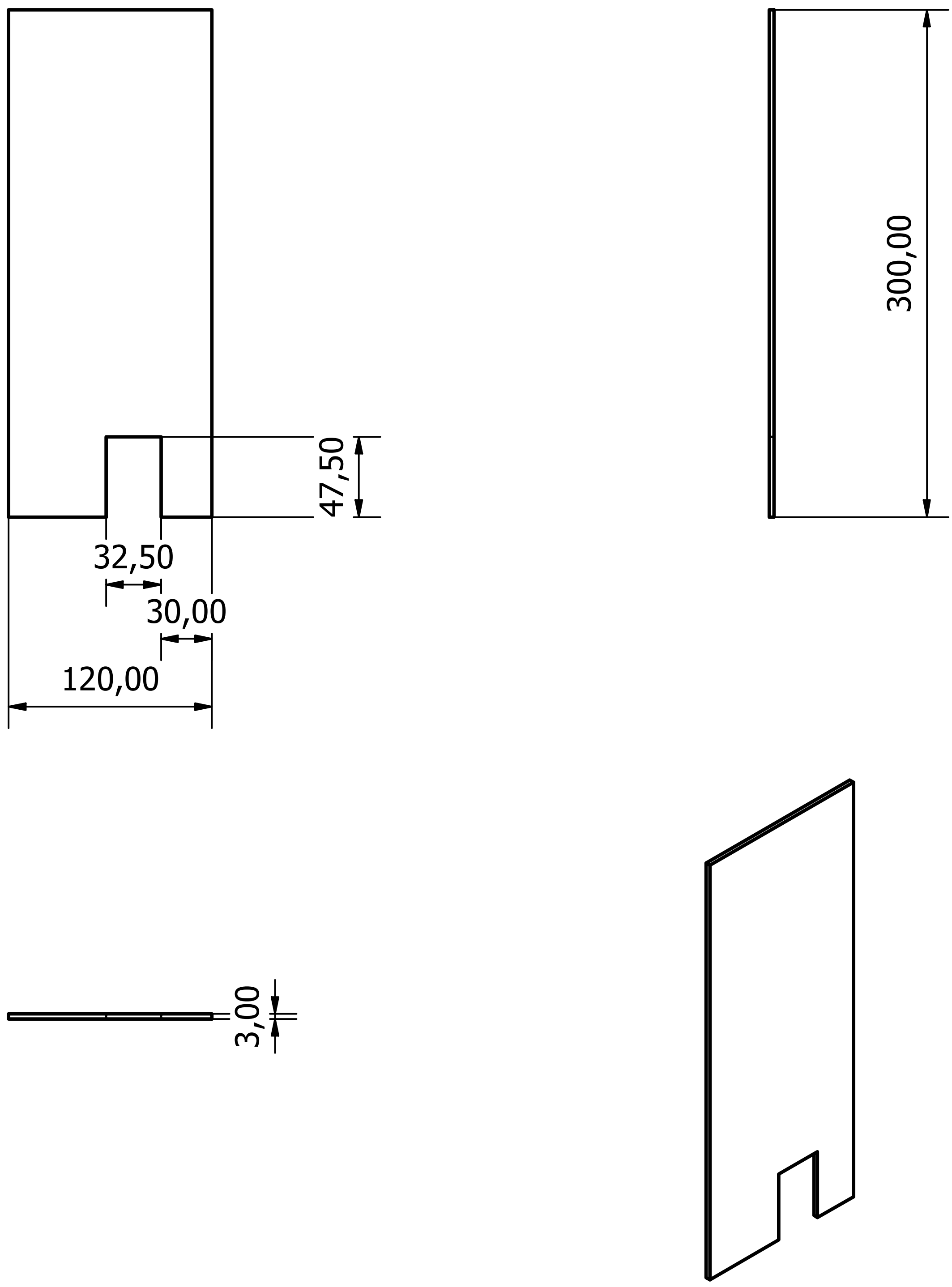

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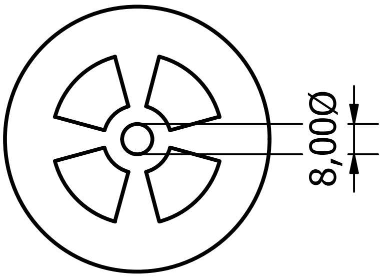

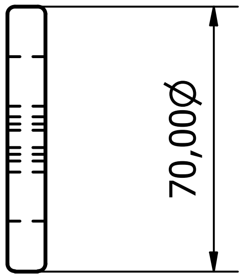

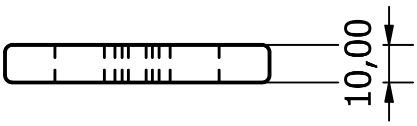

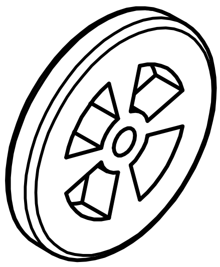

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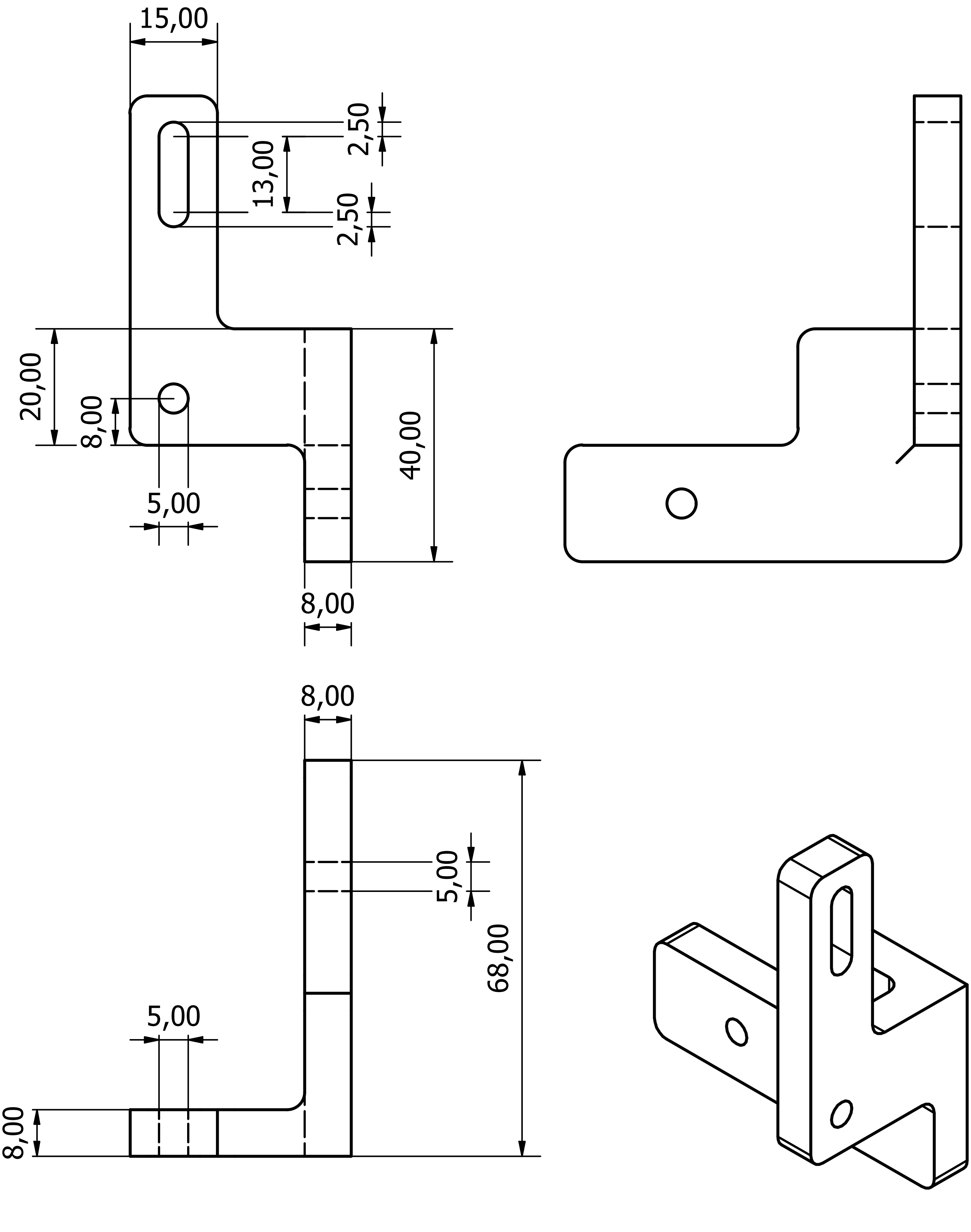

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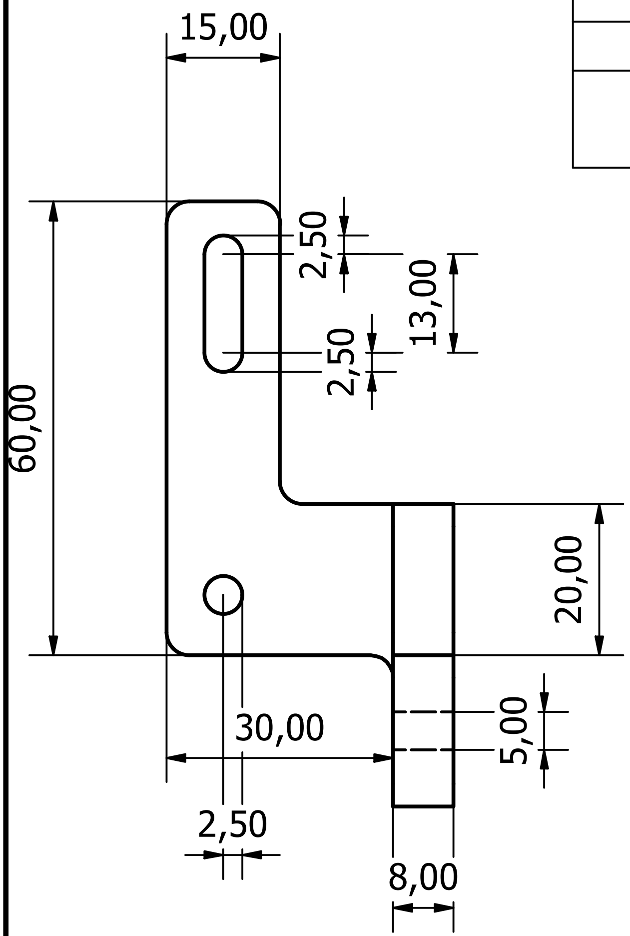

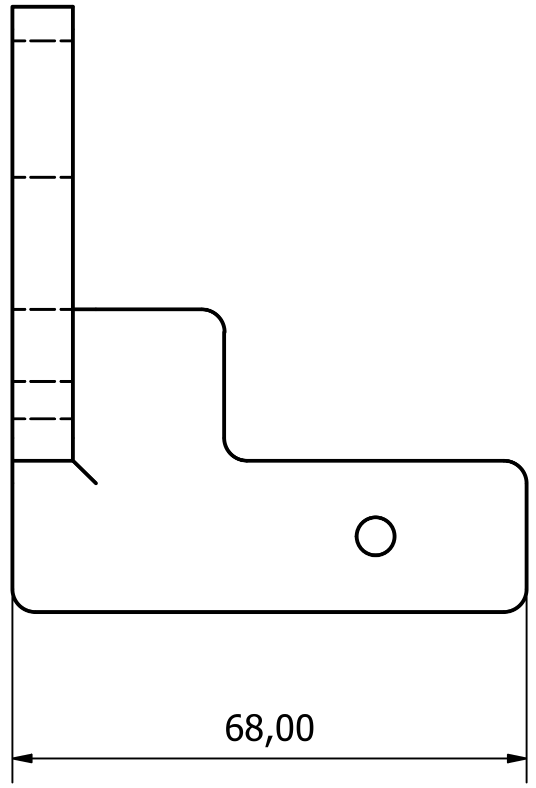

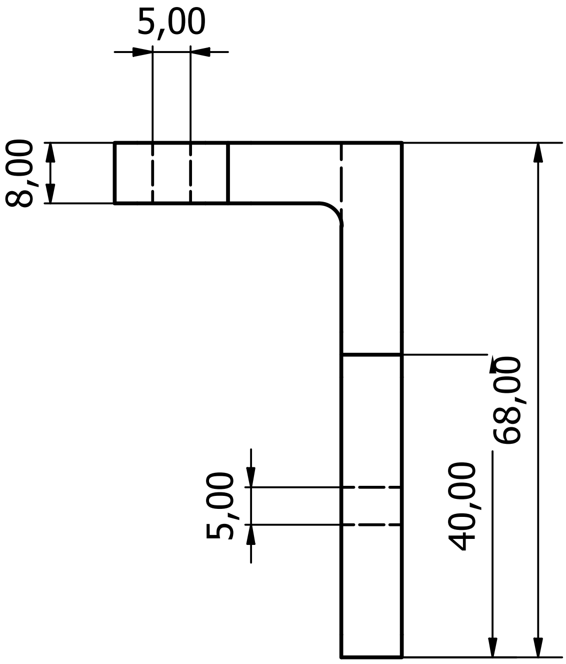

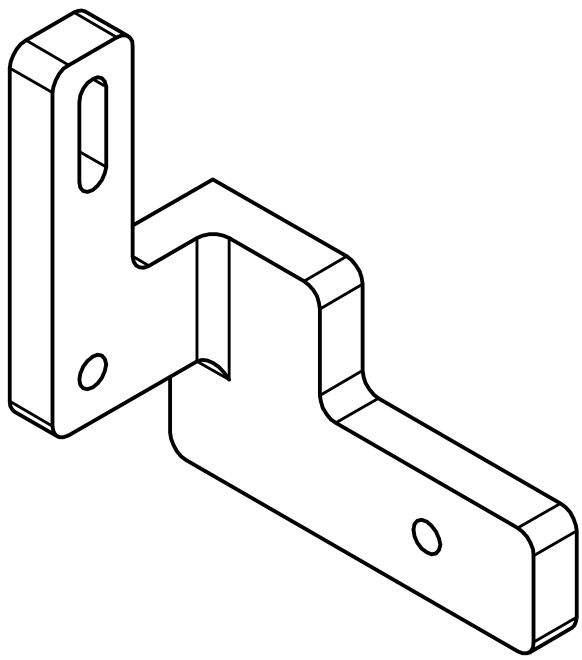

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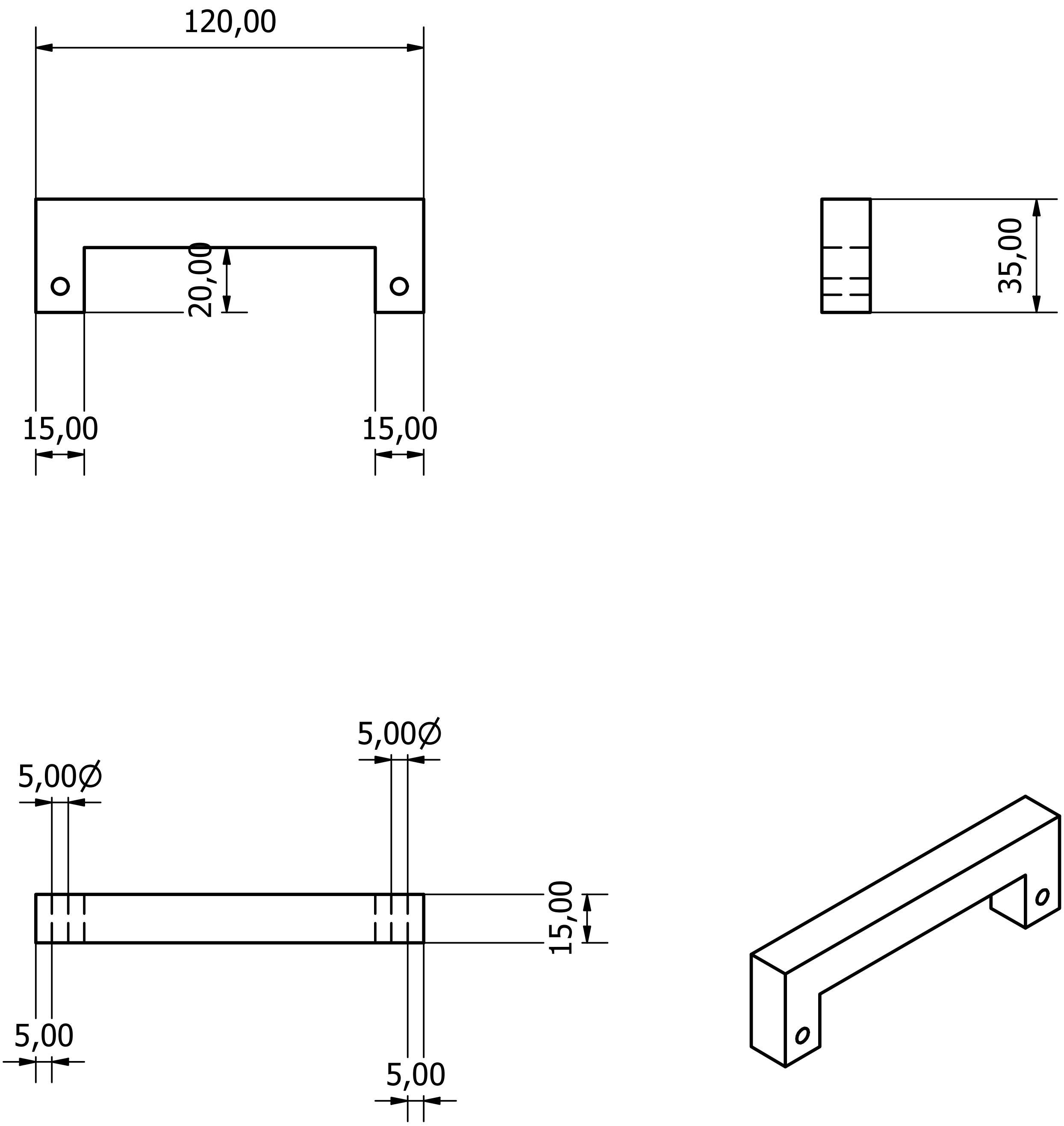

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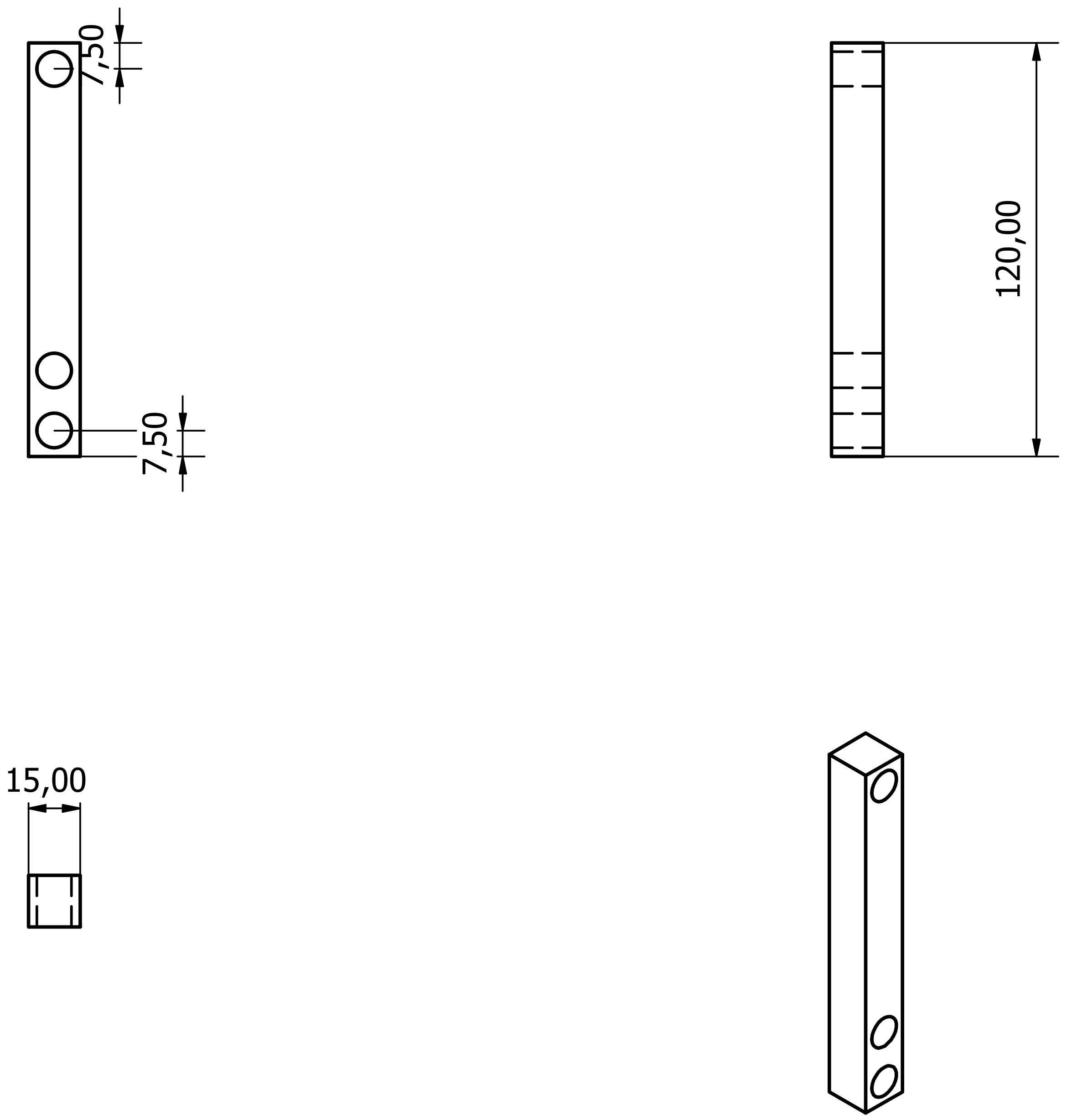

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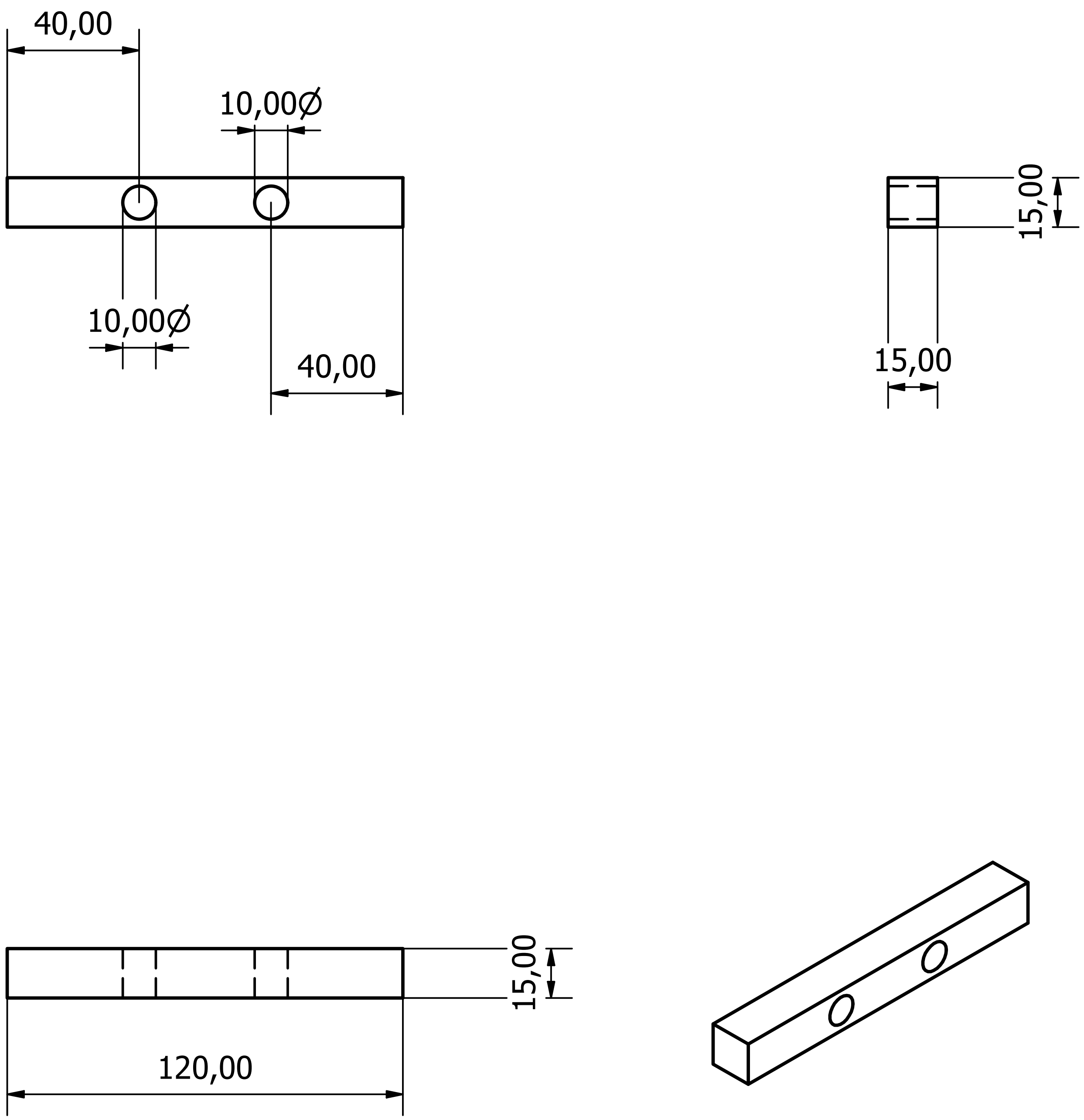

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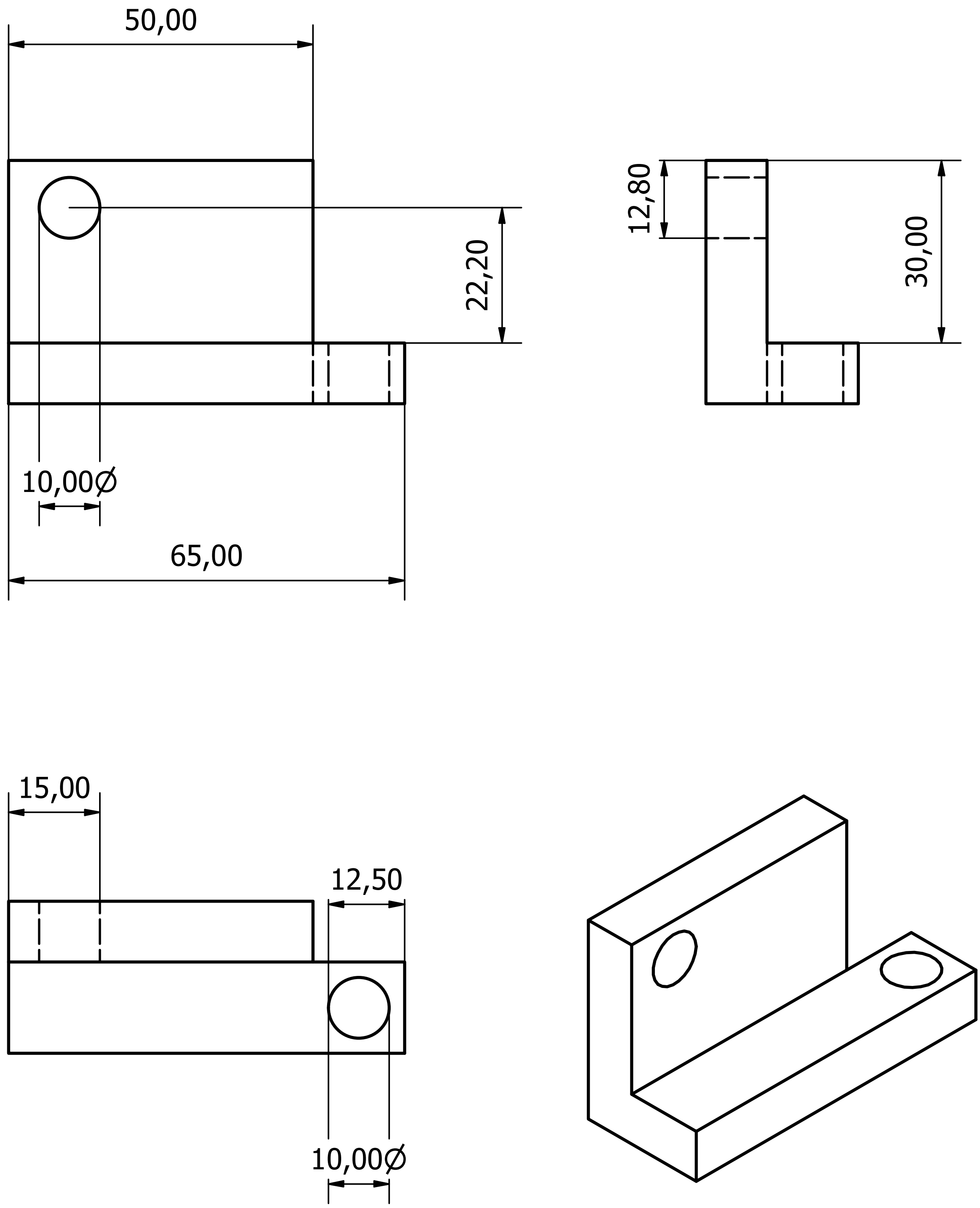

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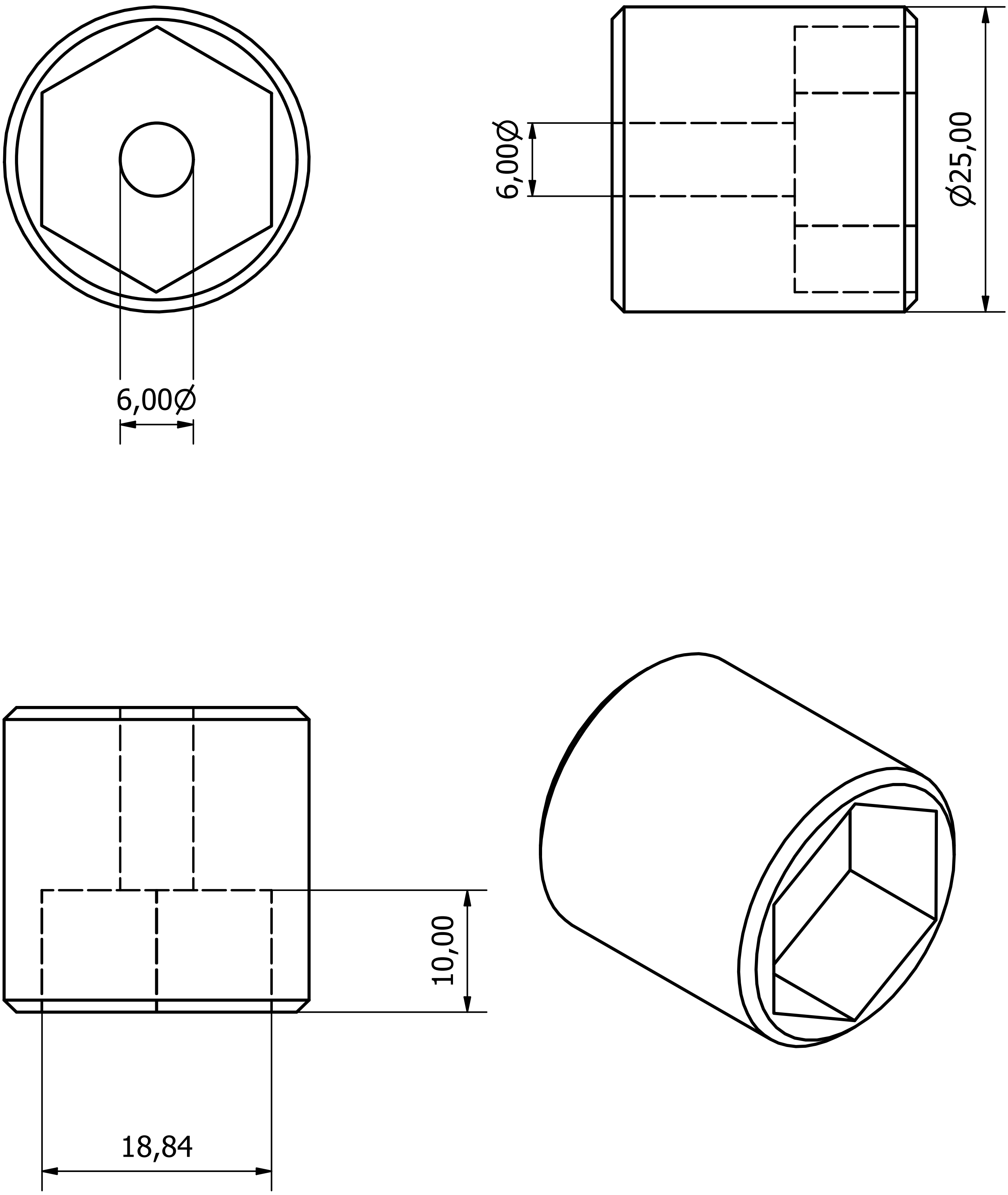

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PARTS LIST		
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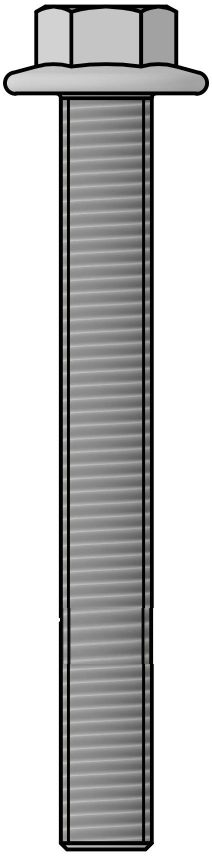
1	1	main_bolt



standard

M12*1.5 100mm

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PARTS LIST		
ITEM	QTY	PART NUMBER
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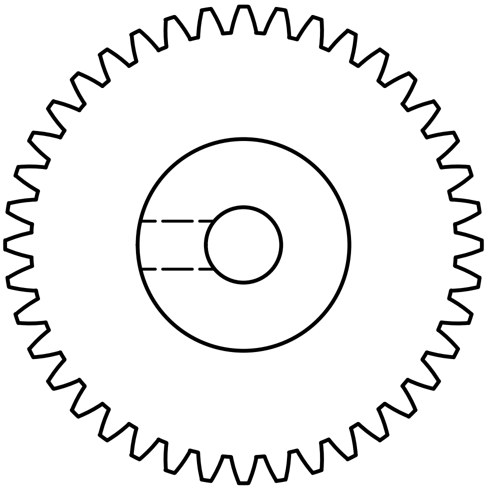

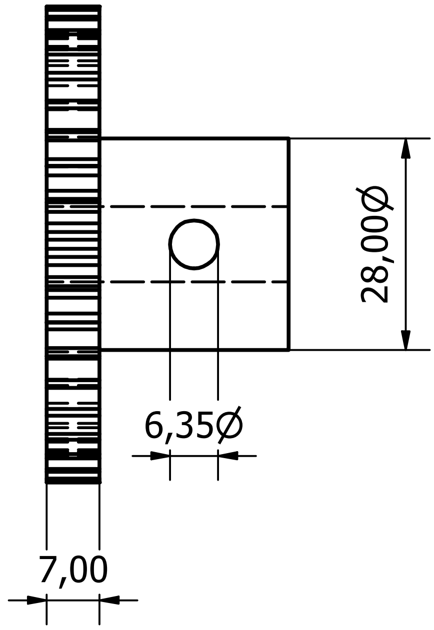

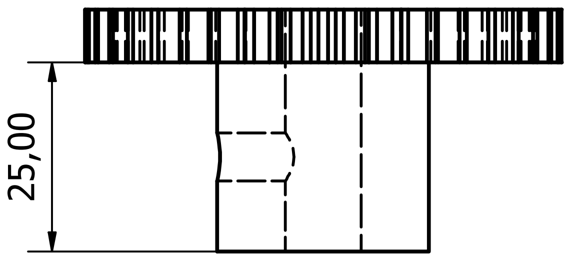

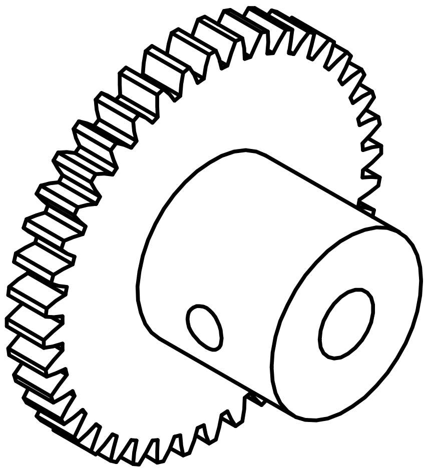

Number of teeth : 40
Module :1.5
diameter :60

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PARTS LIST		
ITEM	QTY	PART NUMBER
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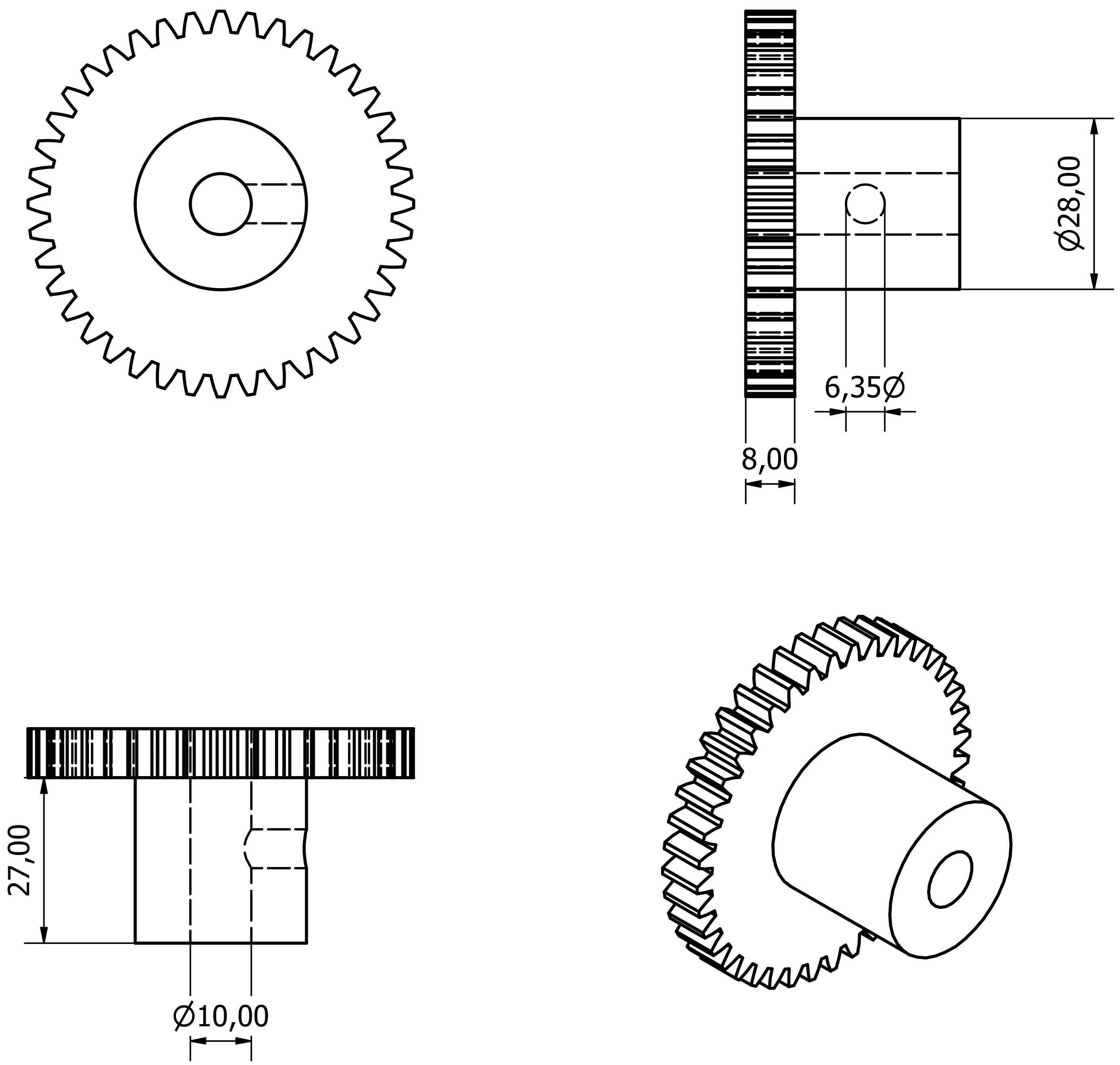

Number of teeth : 40
Module :1.5
diameter :60

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PARTS LIST		
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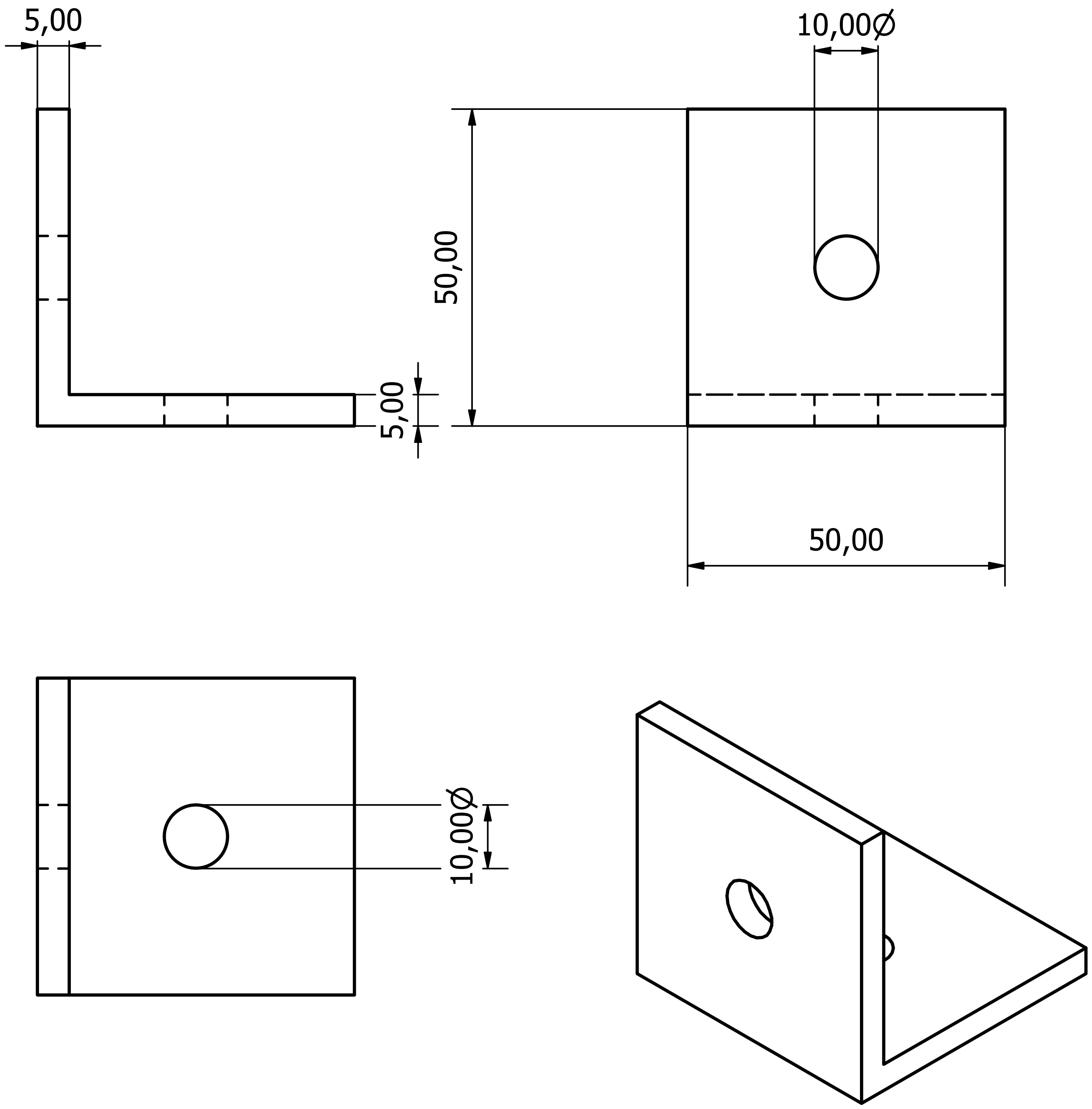

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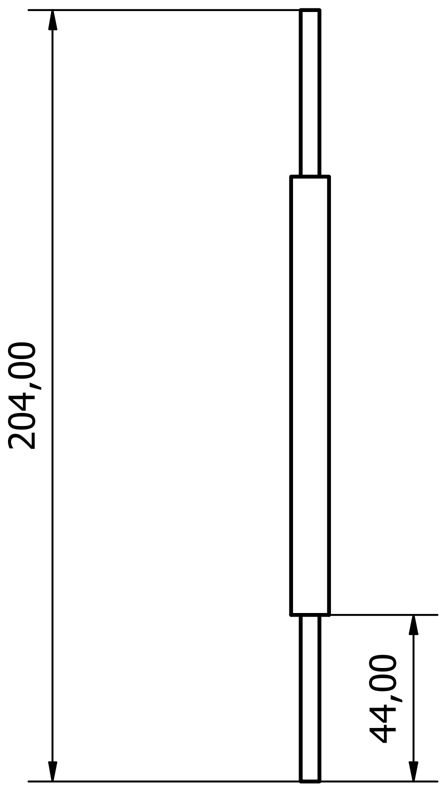
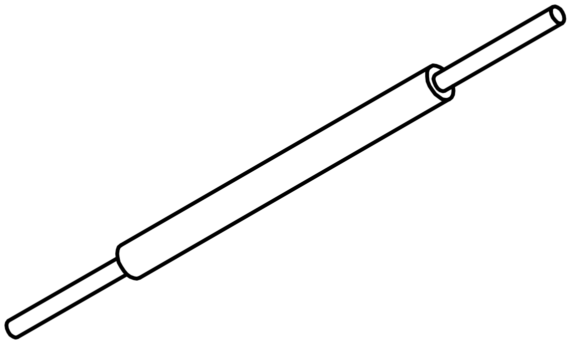
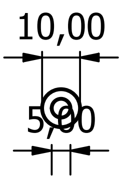
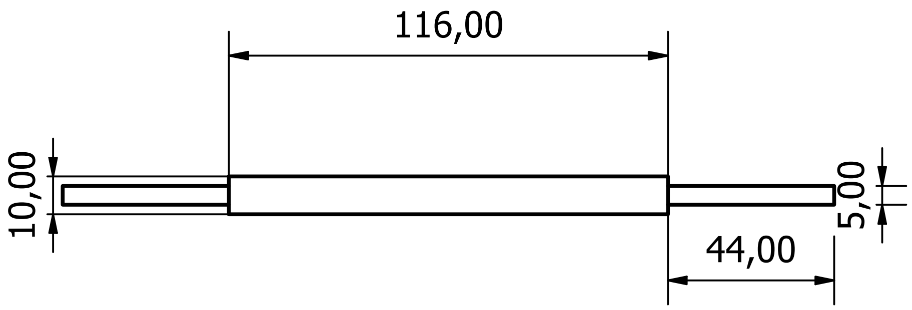
PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Main Shaft

All Dimension in mm









Scale 1:2

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ITEM	QTY	PART NUMBER
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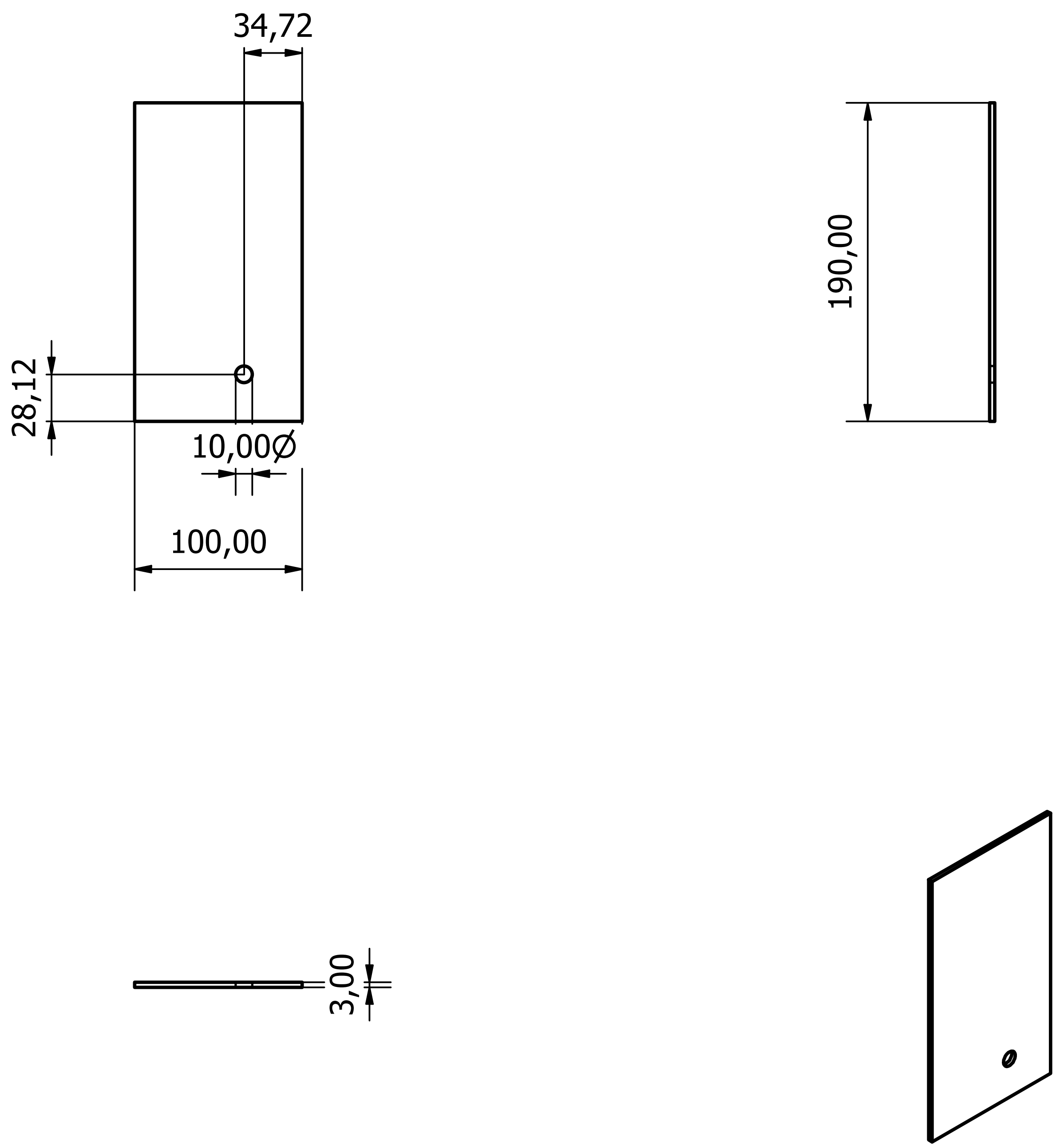

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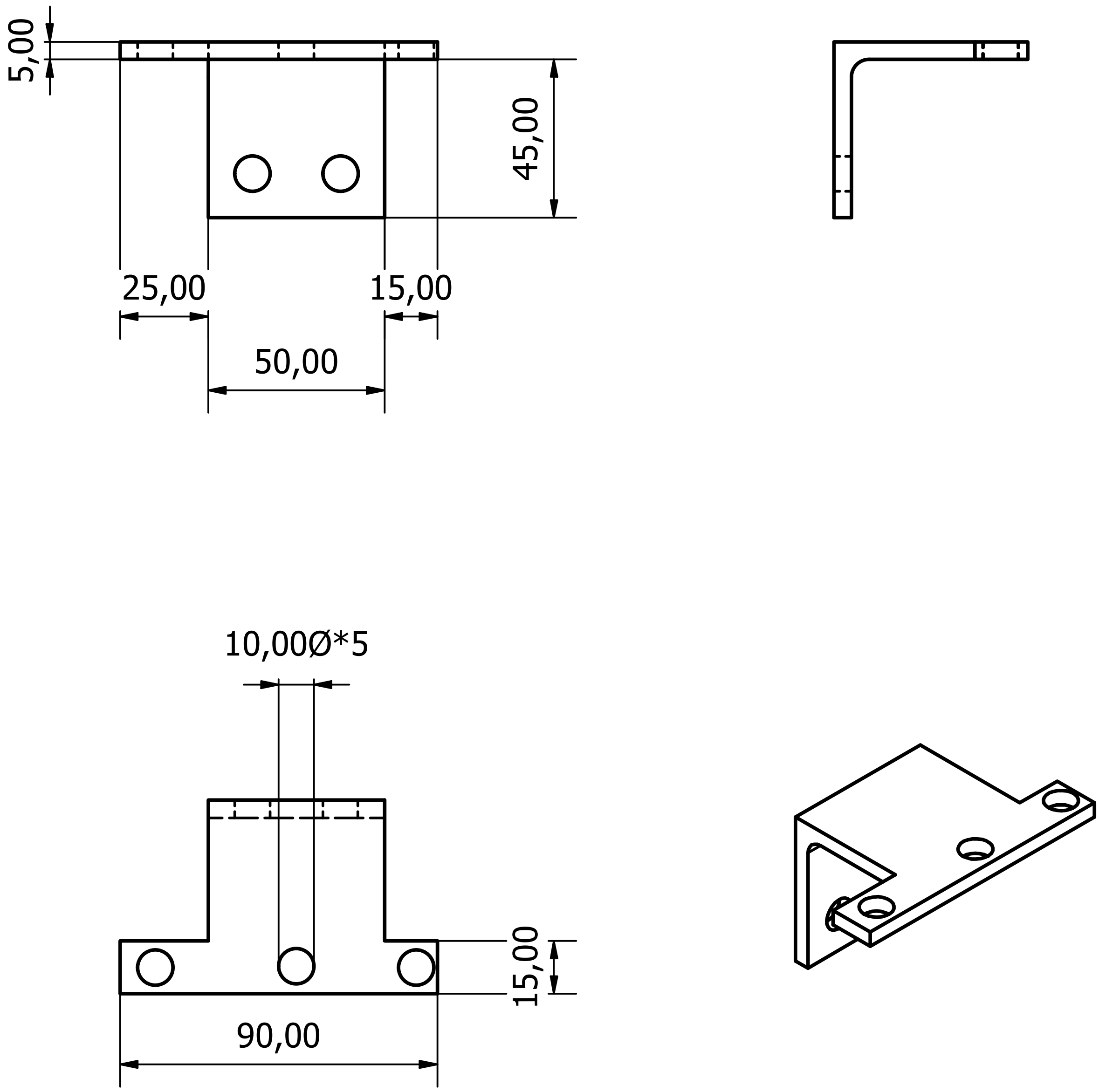
PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	front_motor_holder



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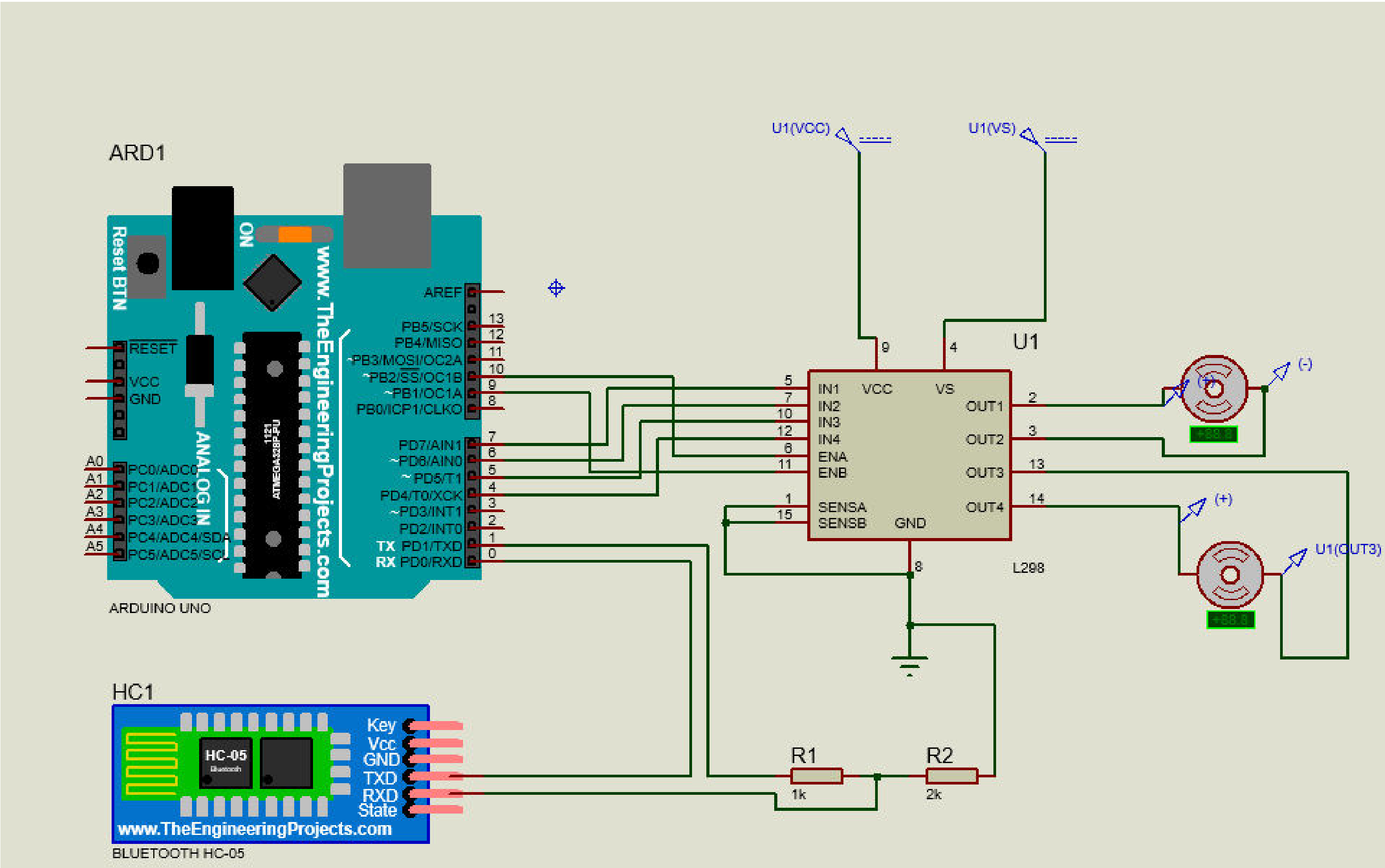
Arduino circuit connections



Arduino code:

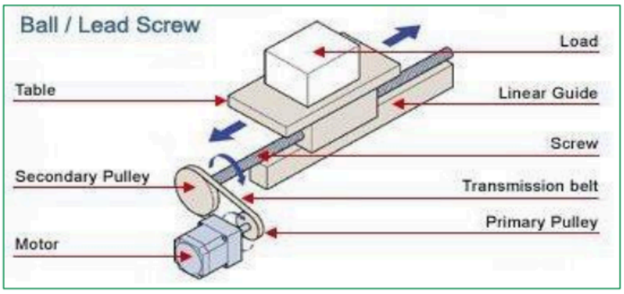
designed by

230630

COST ANALYSIS

NO.	PART NAME	QTY	UNIT COST (₹)	TOTAL COST (₹)
1	Base Plate (180×120)	1	400	400
2	Wheel (R35)	4	180	720
3	Back Wheel Axle	1	180	180
4	Front Wheel Supporter	2	120	240
5	Spur Gear	2	150	300
6	5Nm Motor Stand	1	120	120
7	1Nm Motor Stand	1	100	100
8	Square Rod	1	100	100
9	Small Square Rod	1	80	80
10	Angle	2	60	120
11	Bolt	1	20	20
12	Bolt Mover Support	1	150	150
13	Cylindrical Bolt Support	1	120	120
14	5Nm Motor	1	1600	1600
15	1Nm Motor	1	1100	1100
16	9V Battery	1	60	60
17	Buzzer	1	40	40

Total cost=₹5,450



Size a motor to move a load linearly using a screw-nut mechanism
15

<u>Step 1: Load on table and friction between table and guide</u>

• Determine the load (m) on the table (in kg)

The load m = 0.1kg

• Determine the friction (μ) between the table and guide. For metal to metal contact, μ ranges from 0.1 – 0.3

The friction = 0.2

<u>Step 2: Specifications of the screw</u>

• Determine the diameter (db) and the length (lb) of the screw (in mm). Specify the material too (density, ϱ).

The dia of screw is = 20 mm

The length of the screw = 120mm

The material of screw = mild steel (density - 7.85 g/cc)

• <u>Determine the pitch of the screw pb , i.e. how much the table/nut will advance in one rotations. Units for pitch are mm/rev</u>

The pitch of the screw = 1.5mm/rev

Step 3: <u>Estimate the load inertia</u>*preferred units of load inertia are kg − m2

$$J_L = J_t + J_s = m\left(\frac{p_b}{2\pi}\right)^2 + \frac{\pi}{32}\rho\, l_b\, {d_b}^4$$

Jt → table inertia; Js → inertia of the screw

Putting the values in the formula we get

The load inertia = J = 1.48 x 10^-5 kg·m².

Step 4: <u>Determine if there is a transmission between the motor and the screw</u>

• If using gears/belt-pulleys, determine the diameter and mass (knowing the material and its density, and the width of the gear/pulley) of the driving and driven gears (diameters can be different – depending on the gear ratio)

The diameter of gears = 33mm

• Inertia of a gear/pulley:

The width of the gear = 10mm

The density of the gear = 7.85g/cc

$$J_{gear/pulley} = \frac{\pi}{32}\rho L D^4$$

Thus putting in the formula we get = 9.14×10^−6 kg·m².

- wherein L is the width of the
gear/pulley, and D, its diameter

• If the driving gear/pulley had diameter $Dp1$, and the driven gear/pulley, $Dp2$, and these were different, then the total load inertial would be:

$$J_L = (J_t + J_s + J_{Dp2})\left(\frac{D_{p1}}{D_{p2}}\right)^2 + J_{Dp1}$$

The value = 1.48×10^-5 kg·m² + 2×9.14×10^−6 kg·m².m = 3.31×10^−5kg·m²

Step 5: Determine the torque

• Determine the acceleration torque (ignore the rotor inertia), and,

• The load torque

<u>5.1: Acceleration torque in N-m:</u>

Ta =JL × V / 9.55 × ta

The JL = 3.31×10^−5kg·m²

The v = linear speed = 10 mm/min

The ta = 1.5 sec

Thus putting the values into the formula we get = Ta = 3.85×10^−10N·m

• wherein, if the table speed is specified as a linear speed Vl
, i.e. in m/s, convert it to
appropriate units of r/min: V = Vl(60/pb) - pb is the pitch of the screw

• further, if there is a gear ratio between the motor and the screw connection, then the speed is: V = V ×($Dp2$/$Dp1$)

• ta - acceleration/deceleration time (typically 1 – 2 seconds)

<u>5.2: Load torque in N-m:</u>

Hence, the load torque is: TL =(Fpb/2$\pi\eta$)*(1/i)

The value of F = $FA + mg(\sin\alpha + \mu\cos\alpha) = \mu\, mg$ = 0.2 * 0.1*10 = 0.2 N

The value of pb = 1.5mm/rev

The value of η = 60%

The value of i = 1

Thus putting the values we get the answer = 7.96×10−5 N·m

• Wherein η is the efficiency of the screw-nut pair, which is typically 30 – 70%

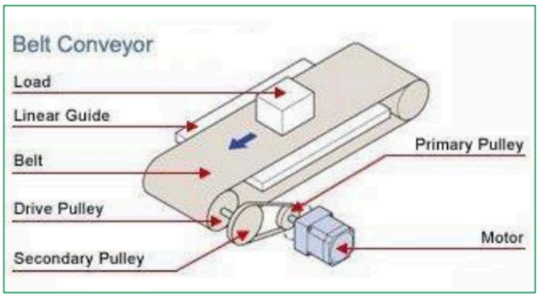
• The gear ratio, i =$Dp1$/ Dp2

<u>Step 5: Determine the torque</u>

$$T = (T_a + T_L) \times FOS = \left(\frac{J_L \times V}{9.55 \times t_a} + \left(\frac{F p_b}{2\pi\eta} \right) \times \frac{1}{i} \right) \times FOS$$

wherein FOS – factor of safety, typically recommended value is 2

T = (3.85×10^−10N·m +7.96×10−5 N·m) * 2 = 1.59×10^−4 N·m.



Step 1: Specify the load to be moved

Load on table and friction between table and guide

• Determine the load (m) on the table (in kg)

The load m = 3kg

• Determine the friction (μ) between the table and guide. For metal to metal contact, μ ranges from 0.1 – 0.3

The friction = 0.2

Step 2: Specify the size of the driving and driven pulleys

The diameter of gear = 33mm

The width of gear = 10 mm

Step 3: Determine load inertia

$$J_L = J_t + J_s = m \left(\frac{p_b}{2\pi} \right)^2 + \frac{\pi}{32} \rho \, l_b \, {d_b}^4$$

Here pb= 0

Thus we get JL = $(\pi /32)\varrho \; lb \; db$^4

Lb = 10 mm

Db = 33 mm

ϱ = 7.85 g/cc

The final value by putting in the formula = 9.14×10 ^−6kg·m^2

Step 4: Transmission ratio

Transmission ratio = 1:1.

Step 5: Determine the torque (including torque to counter external forces, if present)

$Ta = JL \times V / 9.55 \times ta$

$TL = (Fpb/2\pi\eta)*(1/i)$

$$T = (T_a + T_L) \times FOS = \left(\frac{J_L \times V}{9.55 \times t_a} + \left(\frac{Fp_b}{2\pi\eta}\right) \times \frac{1}{i}\right) \times FOS$$

$Ta = JL \times V / 9.55 \times ta$

JL = 9.14×10 ^−6kg·m^2

V = linear speed = 50 mm/min

ta = 2sec

JL = 3.99×10^−10 N·m.

TL = 0 (as pb =0)

T = (Ta + Tl)*2 = 3.99×10^−10 N·m. * 2 = 5.98×10^−10 N·m.

GEAR CALCULATION

Given:

- Number of teeth $z1=z2=40$
- Module $m1 = m2 =1.5$
- Pitch circle diameter (PCD) $d = 60mm$

Basic Gear Parameters:

1. **Pitch Circle Diameter (PCD)**

   $d = m \times z = 1.5 \times 40 = 60$ mm

2. **Gear Ratio (i)**
   Since both have the same number of teeth:

   $I = z2/z1 = 40/40 =1$

   → So, **no speed change** between gears.

3. **Center Distance (a)**

   $a = (d1+d2)/2 = (60+60)/2 = 120mm$

4. **Addendum (ha)**

   $ha = m =1.5mm$

5. **Dedendum (hf)** (standard is 1.25m)

   $hf=1.25\times m=1.875$ mm

6. **Whole Depth (h)**

   $h= ha + hf = 1.5+1.875 = 3.375$ mm

7. **Outside Diameter (da)**

   $da = d + 2 \times ha = 60 + 2 \times 1.5 = 63$ mm

8. **Root Diameter (df)**

   $df = d - 2 \times hf = 60 - 2 \times 1.875 = 56.25$ mm