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Machine Design 3

Design Project

E-Bike Rear Hub

Kyle Flanegan
s220324085

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Student Surname Kyle Flanegan

Signature: Flanegan

Date: 21 / 05 / 2022

Introduction

Due to the increase in fuel costs and the concern about our environment, many people are resorting to other modes of transport. One of the latest popular interests are e-bikes. These are a great, sustainable way to get from A to B or even for exercise. I am required to perform an engineering analysis and design an e-bike rear hub, using the specifications of a mountain bike. The hub will be designed to suit a bicycle that is used for on-road and reasonable flat off-road terrains.

The main objectives for this design are durability, strength and efficiency. Many people interested in this concept of travel may not have previous experience with bicycles and that is why it is important to have a simple design that is user friendly. My design should be compatible to use with all regular mountain bikes.

Throughout this report, I will share the extensive engineering analysis that I performed that led to the final design on the e-bike rear hub. Different materials were compared to determine which one will meet the requirements of the bike hub.

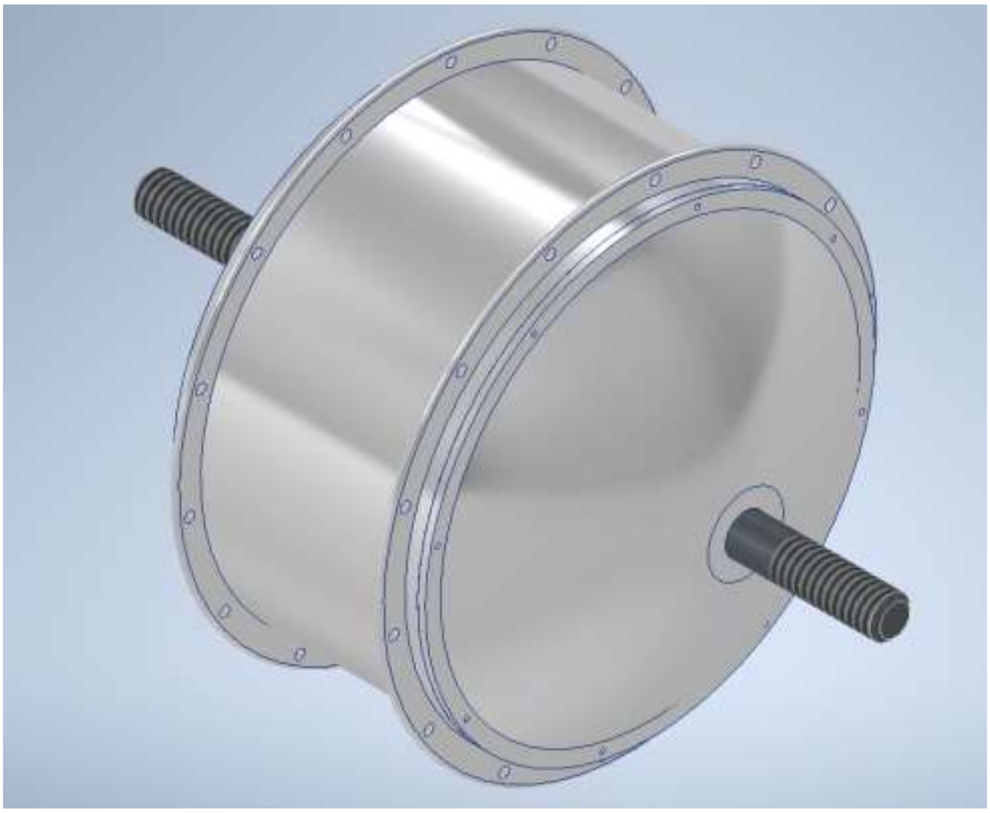

Figure 1: Final Design of E-bike Rear Hub

Factors Influencing Design

The e-bike hub does not act as a comprehensive electric bicycle conversion. This specific product is used as an assistive mechanism, as the motor supplements peddling power instead of adding additional power.

Compatibility

The rear hub needs to be compatible to use with all regular mountain bikes. This means we will have to take into consideration all the specifications of a mountain bike.

Functionality

The motor is required to aid the rider on request, which means I will have to include an in-built motor. An e-bike hub is environmentally friendly and does not use petrol, which means petrol motors need to be avoided in the design.

In the frame of the mountain bike, you will find a DC power supply that is connected to a small battery powered motor included in the rear hub. The motor runs on the power supply and in turn provides the rider with the assistance that they need.

E-bikes can make use of either speed sensors or torque sensors to regulate e-assist. Speed sensors detect the rider's pedalling cadence whereas torque sensors measure the amount of torque the rider is putting into the pedals.

Materials

This product will be used outdoors in all sorts of weather conditions. It is important to choose the correct material that can withstand these weather conditions as well as meet the durability and strength requirements.

Engineering Analysis

Throughout my engineering analysis I made logical decisions that were based on assumptions where necessary. All factors that would affect the design of my product were considered and delt with. Below you will find the detailed explanation of how I came to a final design for an e-bike rear hub.

Design Specifications

The task that has been assigned to me is to design an effective yet affordable rear hub for an electric bike. The first step would be to understand the requirements of the task. There are only two major requirements for the rear hub, one being eco-friendly. We have to design a e-bike hub that will not pollute the environment. In order to make this possible I will have to include a DC motor in the design of the hub. The bike hub needs to be compatible with all regular mountain bikes. Individuals should be able to purchase the product and assemble it to their bicycle without any issues. This brings me to the next requirement; I will have to take into consideration all the specifications of a regular sized mountain bike. All these factors will be taken into account during the design and calculations.

Material Selection

Housing

As mentioned previously, we are dealing with a product that will be used outdoors, which is why we have to consider the durability, strength and the weight of the materials that will be used. I will start with the housing of the rear hub. This component will experience the largest angular velocity and therefore the most angular resistance. To get the most power out of the motor, a light, yet strong material will need to be considered for the housing as this will produce the least rotational resistance.

A few materials to compare:

1. Mild steel
2. Aluminium
3. Stainless steel

Steels are usually stronger than aluminium, however, they will produce more rotational resistance. Mild steel is one of the lighter steels but is 2.5x denser that aluminium. A mild steel that is as light as aluminium will not be as strong and will most likely crack and break.
If we take a look at stainless steel, we will see that it is a very strong material and will meet the durability requirements of the product. On the other hand, it is a very heavy material, with aluminium being 1/3 the weight of stainless steel.
After extensive research, the material that will be used in the design of the hub is aluminium. Steels are stronger, yet too heavy to use in the design. Aluminium is not as strong as the steels, but it has a much better strength to weight ratio. This is important because the hub needs to be light in order to produce the best performance. Just like aluminium 5052, aluminium 1100 has excellent corrosion resistance, however, its strength is lower (7 Things to Consider When Choosing an Aluminium Grade, 2022). I will therefore be using **Aluminium 5052** as the material of the e-bike rear hub. The materials properties are shown below (MatWeb, 2022):

Tensile Strength, Ultimate = 228 MPa
Tensile Strength, Yield = 193 MPa
Modulus of Elasticity = 70.3 GPa

Planetary gears

When it comes to selecting a material for the gear system, we will have to use grey cast iron. Cast iron is hardened and has very high compressive strength which makes it a very durable material. All gears, including the ring gear, three spur gears and the sun gear will all be made from Cast Iron.

Conceptual Ideas for Design

There are a few designs one could use to achieve the goal of the product. Some designs may be cheaper and more effective than others. I designed the stator in inventor to give a good understanding of how the entire hub would look. The design I chose is a simple planetary gear system that works with a stator to get the rotation the gears needed. A ring gear will be attached to the hub housing as shown in the image alongside.

Figure 2: Ring gear in assembly

The 3 spur gears are attached to the planetary gear plate which in turn fits onto the cover plate. The cover plate is then attached by tiny diameter 1mm screws to the with the ring gear side of the housing. The sun gear is found on a plate that is attached to the stator housing. This gear fits between the 3 spur gears and forms part of the planetary gear system.

The stator rotates due to the magnetics on the inside of the of the housing. This rotation in turn, rotates the sun gear. Once the sun gear rotates, the planetary gear system starts to move the ring gear. Because the ring gear is attached to the hub and essentially the wheels, the wheel will start to rotate.

The hub is required to fit on all regular mountain bikes. Regular mountain bikes have a wheel size of 26 inches in diameter and have around 28 spikes (Bike Exchange, 2022).

In the image alongside, there are tiny holes for the spokes of the mountain bike wheels to be attached (precisely 14 on each end).

Figure 3: Outer holes for wheel spokes

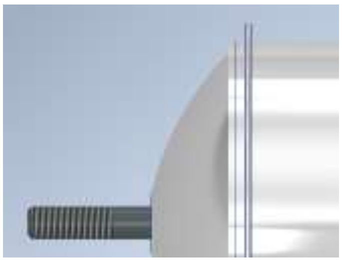

Figure 4: Shaft End to Attach Clamp

The shaft is attached to the stator and is of 148 mm in total length. This length allows 30 mm of each end to be visible outside of the housing, 20 mm of which is threaded. This thread allows the user of the product to attach the shaft clamp to secure the hub in place.

Calculations

If we consider a case of the rider going up a slope of 12 degrees at 15 km/h and having a combined weight of 100 kg we can perform the calculations as follows:

$$V = 15\ km/h$$

$$\theta = 12°$$

$$\mu_f = 0.027$$

Now,

$$V = ((15 \times 1000)/60)/60$$
$$= 4.167\ m/s$$

$$F_g = mg$$
$$= (100)(9.81)$$
$$= 981\ N$$

$$F_N = F_\perp = F_g \cos(\theta)$$
$$= (981)\cos(12)$$
$$= 959.56\ N$$

$$F_f = \mu_f F_N$$
$$= (0.027)(959.56)$$
$$= 25.91\ N$$

$$F_\parallel = F_g \sin\theta$$
$$= (981)\sin(12)$$
$$= 203.96\ N$$

$$F_{app} = F_\parallel - F_f$$
$$= 203.96 - 25.91$$
$$= 178.05\ N$$

In order to maintain this speed up the incline, the expected force required needs to be greater than or equal to 178.05 N.

If wheel diameter is 26” (0.6604 m), the torque required to for this scenario can be found as follows:

$$T = F \times r$$
$$= (178.05)(0.3302)$$
$$= 58\ N.m$$

Conclusion

The aim of this task was to design a rear hub that will fit any regular mountain bike that assists the rider in using no petrol or fuel. There were a few factors that influenced the design which were discussed, and a final product was produced. As you would see in the engineering analysis, a conceptual design was chosen that incorporated a planetary gear system that is run by a stator which gets its power from a DC source. The gear train helped decrease the revs of the motor by increasing the torque output.

In conclusion, the hub that I designed is a simple yet effective product that will indeed attract new individuals to idea of a clean and safe form of transport as well as an opportunity to explore nature without exerting too much energy. Individuals will find this product easy to install with little to no engineering experience.

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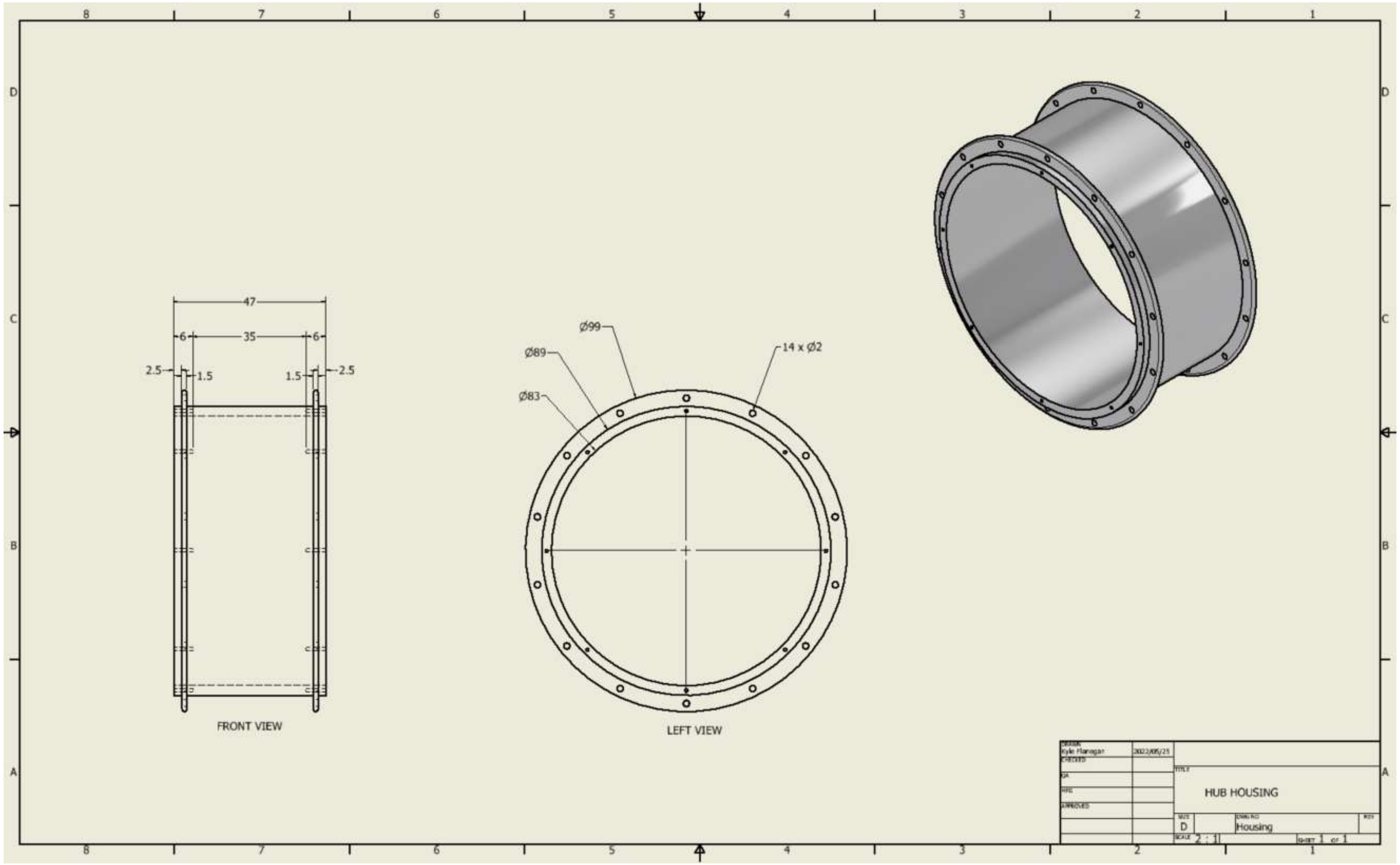
Appendices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35
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1.5
1.5
2.5
FRONT VIEW
Ø99
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Ø83
14 x Ø2
LEFT VIEW
DRAWN
Kyle Flanagan
2022/05/25
CHECKED
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MFG
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TITLE
HUB HOUSING
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Housing
REV
SCALE 2 : 1
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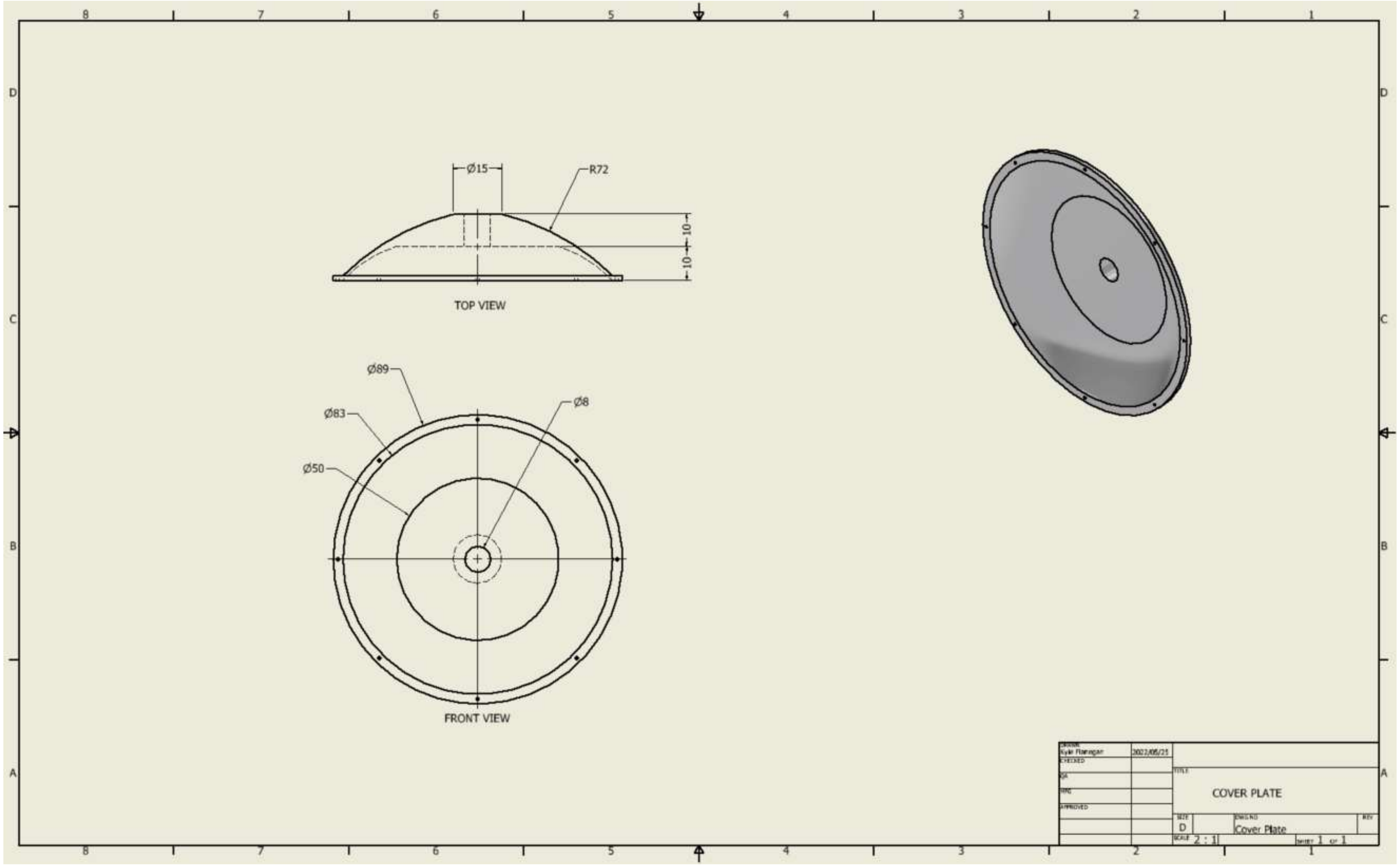
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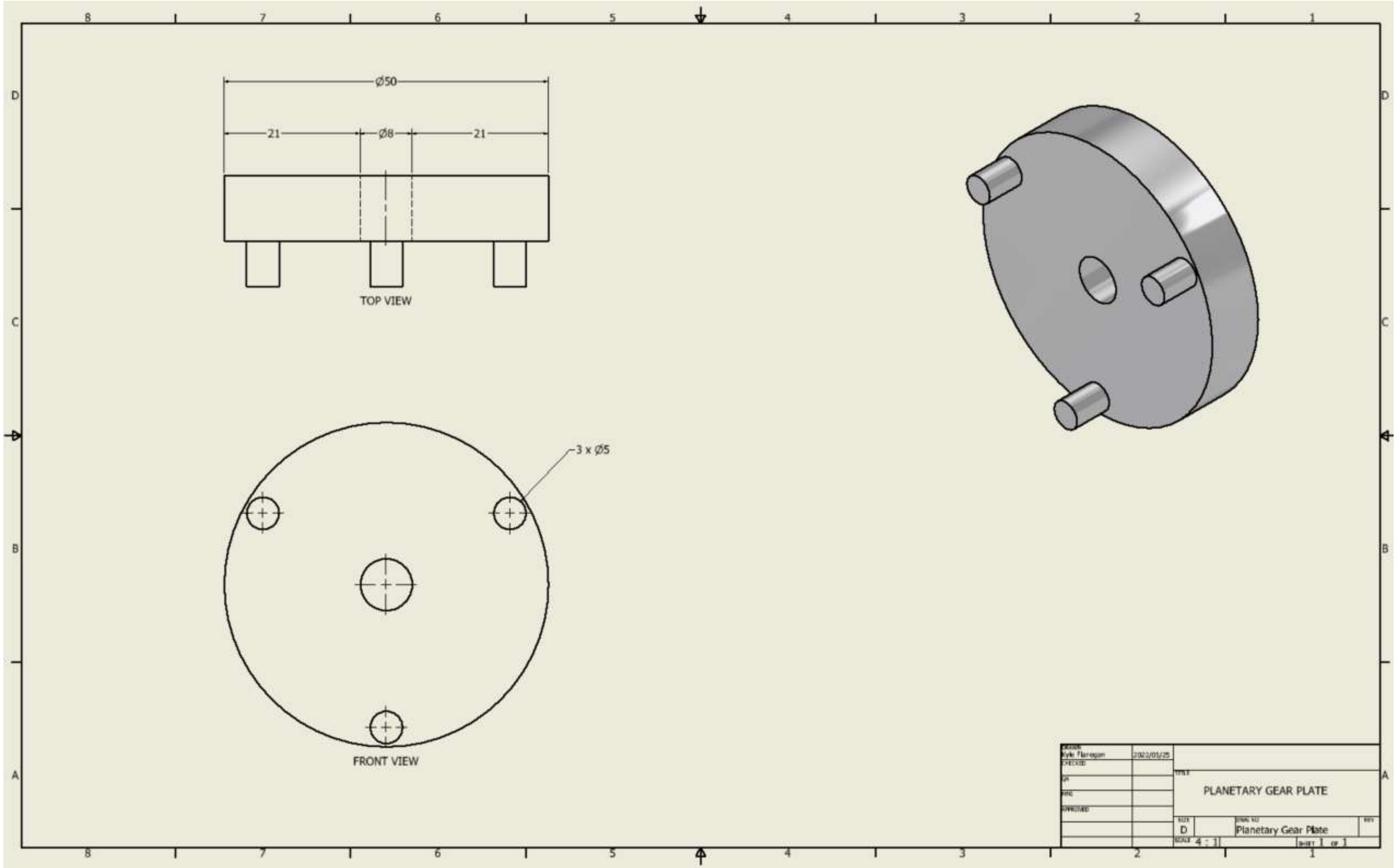
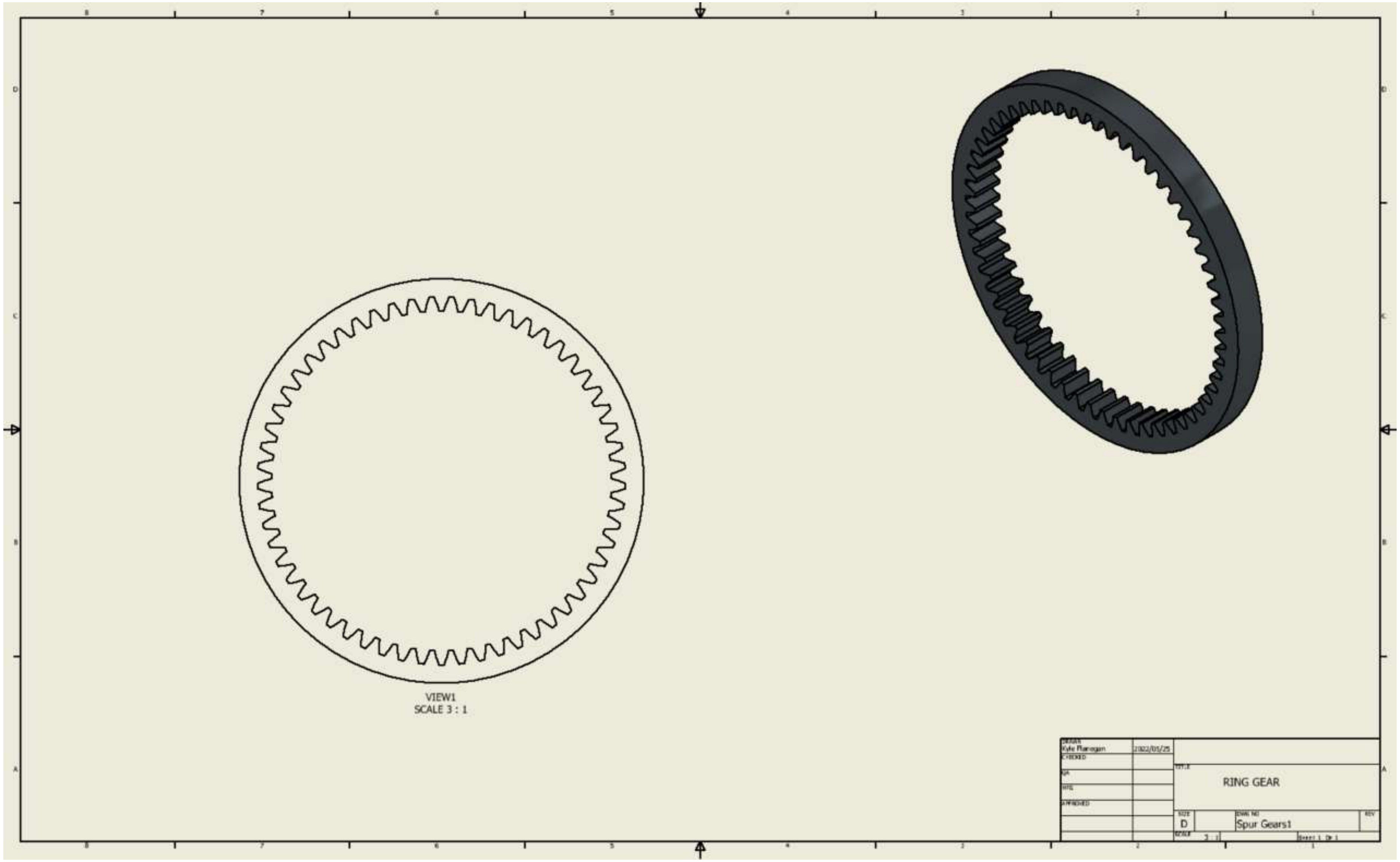


Ø50
21
Ø8
21
TOP VIEW
3 x Ø5
FRONT VIEW
Kyle Flanagan
2022/05/25
CHECKED
PLANETARY GEAR PLATE
D
Planetary Gear Plate
4 : 1
1
1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Kyle Flanagan
2022/05/25
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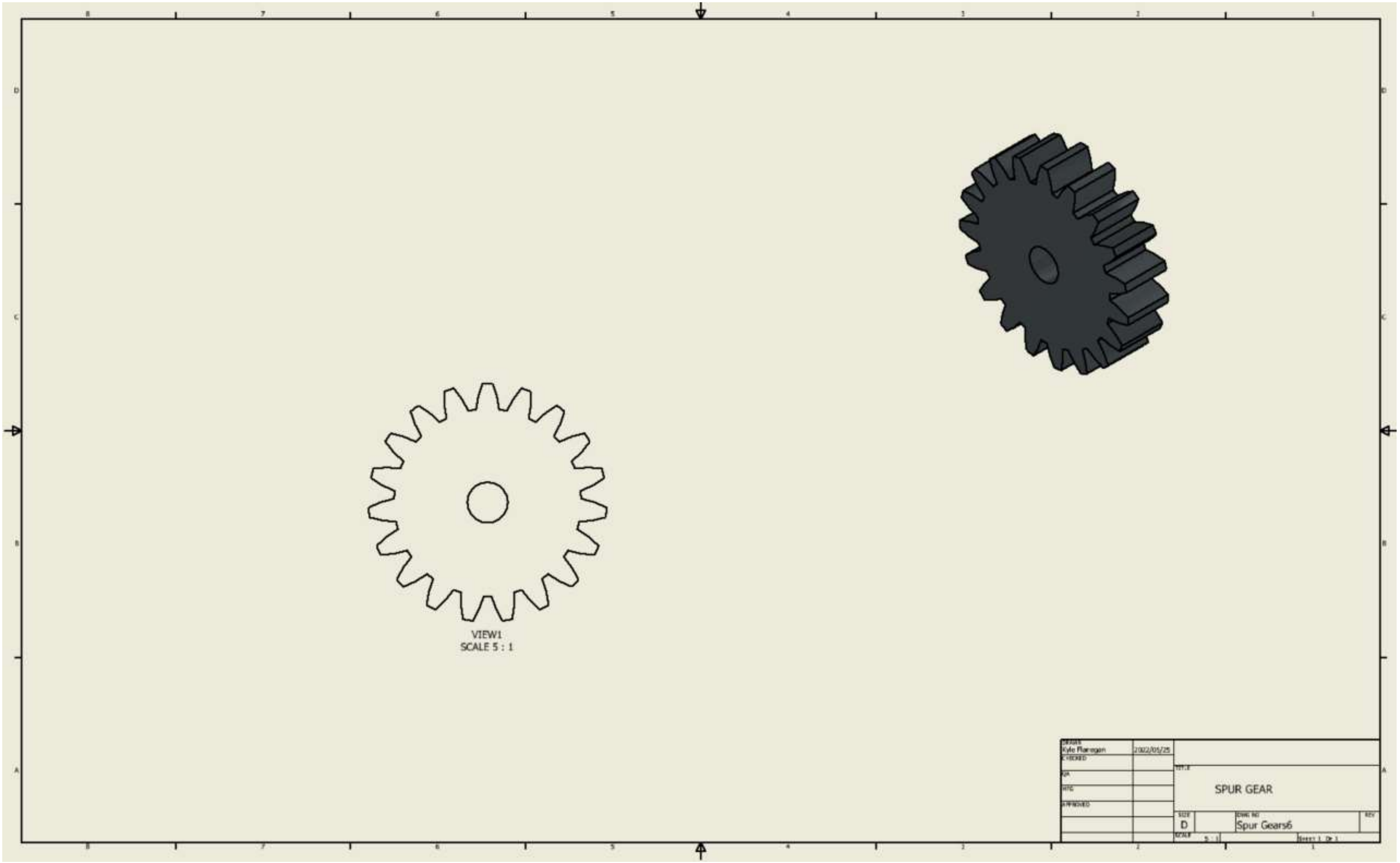
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2022/05/25
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Spur Gears6
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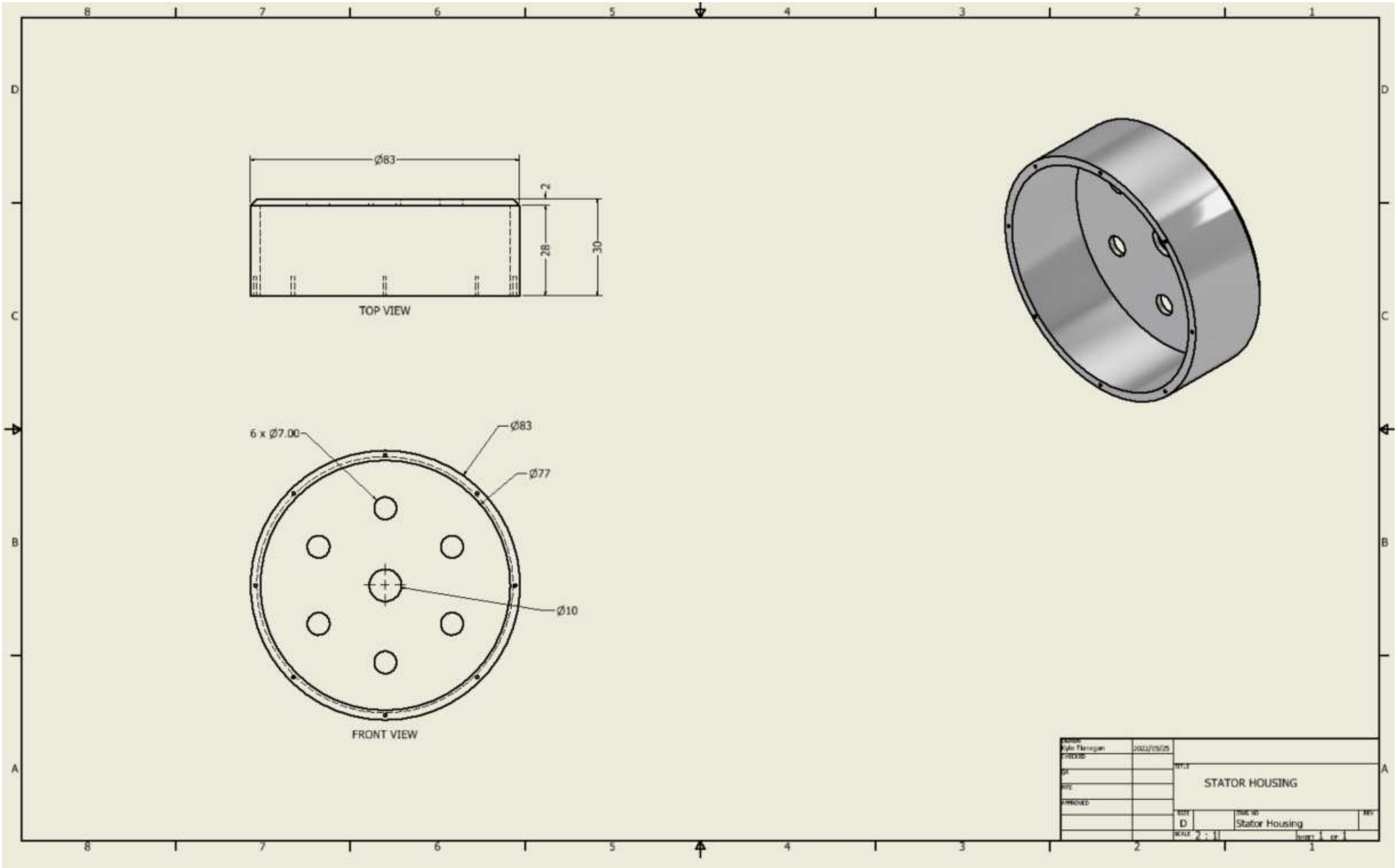

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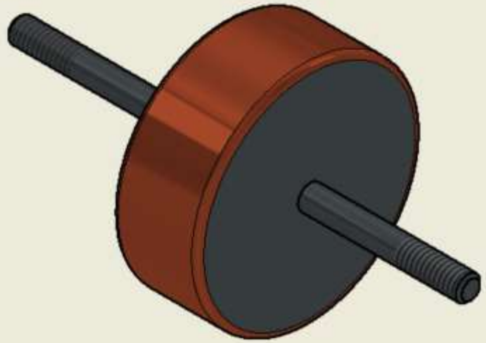

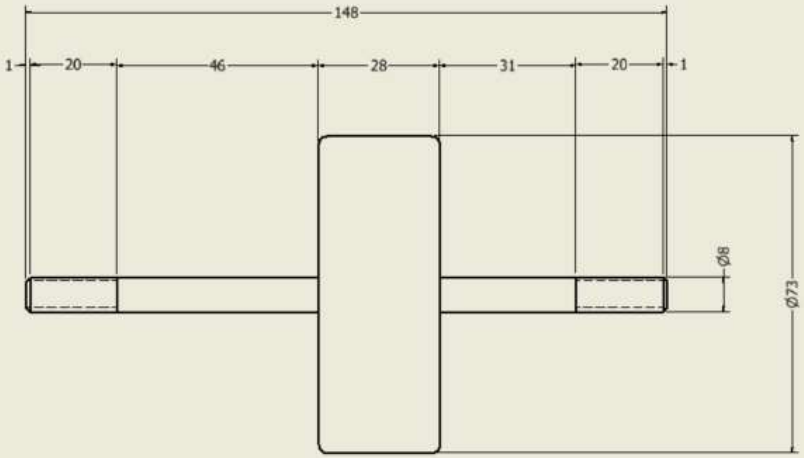

FRONT VIEW

DRAWN Kyle Flanagan	2022/05/25	
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APPROVED		SIZE D / DWG NO Strator / REV
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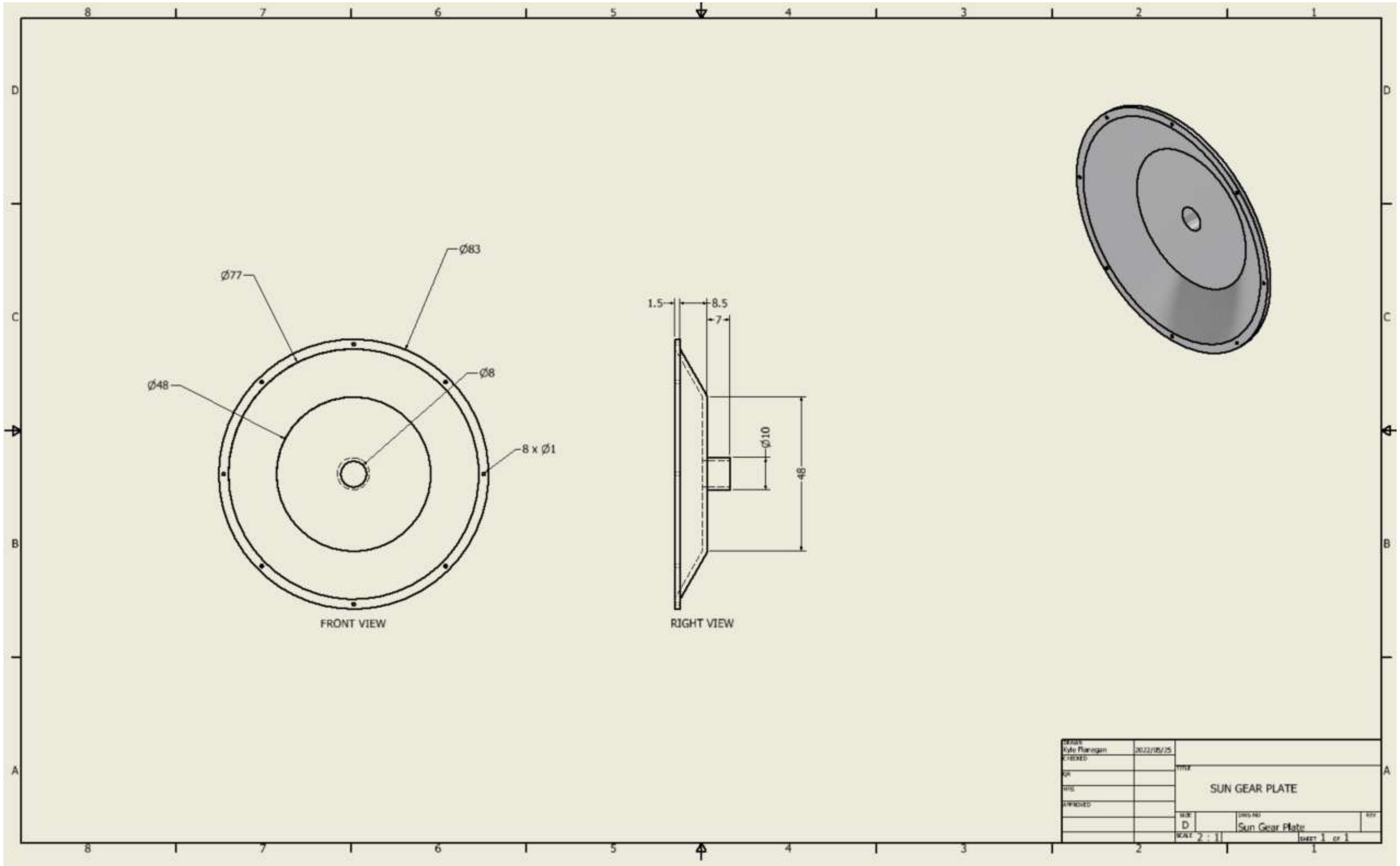

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Ø77
Ø48
Ø8
8 x Ø1
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8.5
7
Ø10
48
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Kyle Flanegan
2022/05/25
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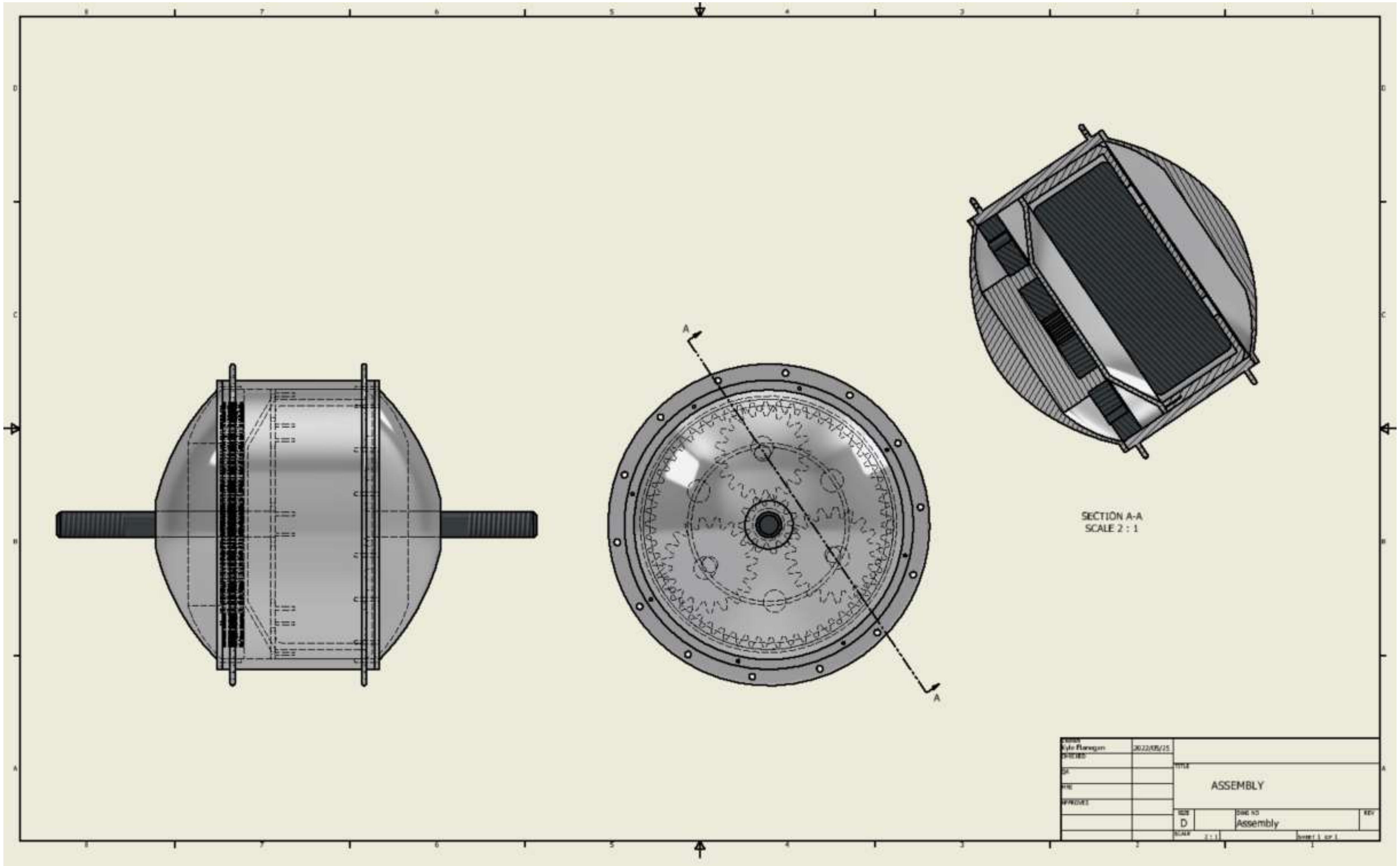
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Kyle Flanagan
2022/05/25
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