NELSON MANDELA UNIVERSITY

Machine Design 3

Design Project

Two-Axis Machine Tool Table

Figure 1: Highcross Designs. 2022. What Is CNC Machining? And Is It Right for You?. [online] Available at: <https://www.highcrossdesigns.com/news/what-is-cnc-machining/> [Accessed 2 May 2022].

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Student Surname Kyle Flanegan

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Introduction

CNC machining is a manufacturing technique that is used for surfacing of stock and in the making of grooves and slots. It is an automated process that uses computer-aided manufacturing software and computer-aided design. There are a variety of machine tables that can be used during the milling process including 2-axis, 3-axis, 4-axis tables.

The objective of this project is to design a safe and effective 2-axis machine tool table that can withstand the stresses that it will face during the CNC milling process. Throughout this project, I will share the detailed description of my design process while displaying the factors that influenced my final model. Comparisons of materials and design features contribute towards a final design. Logical decisions were made based on assumptions which can be seen in my engineering analysis.

In order for the table to function correctly with extreme precision, calculations of the forces and frictions on the table will be made. The correct materials will then be used to design parts that can endure such conditions.

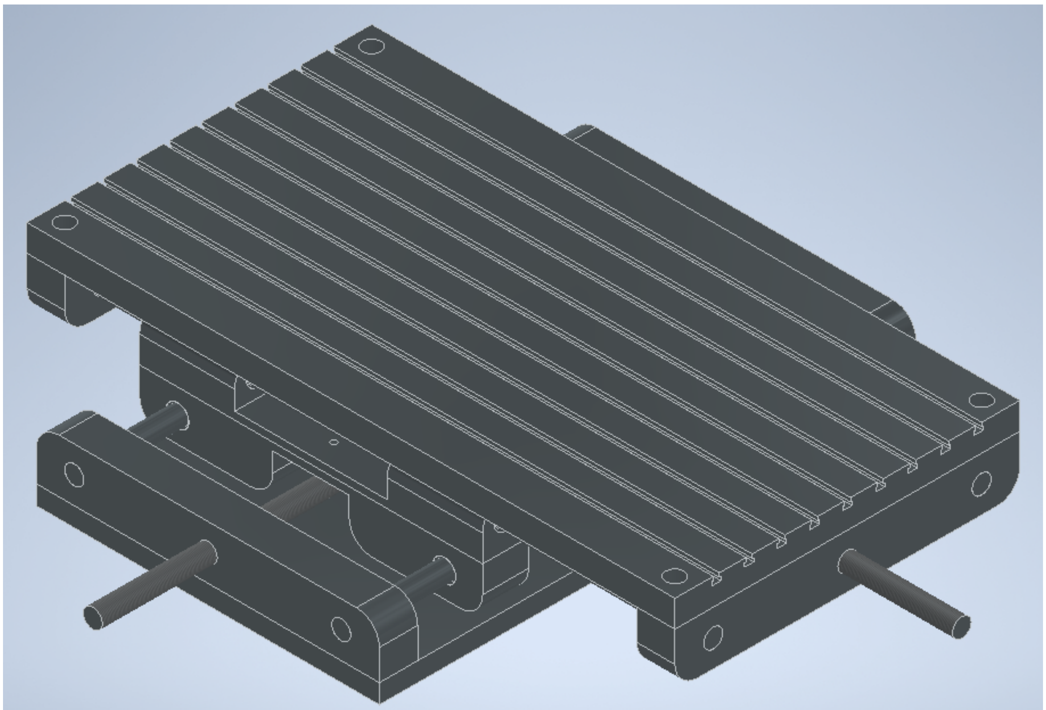

Figure 2: 2-Axis Milling Machine Table

Factors Influencing Design

Functionality

As mentioned before, the table that I am required to design needs to have 2-axes. This essentially means that it will operate along the XZ plane, with X-axis being left to right and the Z-axis being front to back.

Accuracy and Liability

The final assembly of the table needs to fit perfectly in order to have an effective planar movement. A factor of safety will be applied in the design. This will allow the milling process to run smoothly with and efficiently with much accuracy.

Strength

It is crucial that the table is held securely during the milling process for ultimate safety and efficiency.

Cost

As engineers, we are required to perform a cost analysis in order to produce a realistic design that businesses and individuals can afford to use. The cost of materials and the availability of parts will be considered.

Materials

The use of standard materials will make the production of the table easier, quicker and cheaper. While considering all these factors, I need to ensure that the materials selected to use are strong and durable to meet the design requirements.

Availability

The cost of the table will be determined by the availability of materials and parts. It is always a good idea to make use of standard parts where possible as some suitable materials may be difficult to source and more expensive.

Engineering Analysis

It is essential to conduct an engineering analysis when designing mechanical parts. All factors that could influence the final design need to be considered and calculated in order to produce the exact design that is required of me. The following is a detailed description of design the design process.

Design Specifications

My task is to design a table that can accommodate a work area of 400x400mm. The surface area of the table will therefore need to be larger than that of the work area. The tool that will be used along with my table design is driven by a 10 kW motor which produces a maximum spindle speed of 4000rpm. The maximum diameter of the tool is specified to be 30mm. These requirements will be factored into the design of the machine tool table.

Material Selection

Choosing the right materials to use when designing mechanical parts is a very important step in the design process. Materials have an impact on the cost, strength and durability of the mechanical part. When deciding on the correct materials to use in my design, I had to consider the conditions under which the materials would work.

Considering the conditions and the forces that the machine tool table would work with, there are two different materials that I can choose between based on their mechanical properties. These being stainless steel and cast iron, which are the two most popular materials used when it comes to the manufacturing of mechanical components due to their reliability and durability. If we take carbon steel for example, it does not contain chromium, which protects a material from moisture, and therefore will rust (Carbon Steel: What You Should Know, 2022).

The main difference between steel and cast iron is their carbon content. Carbon is responsible for the malleability of the iron. The more carbon in the material, the more malleable the iron will be. The carbon content of cast iron is generally more than 2% as appose to steel having less than 0.5% carbon. As a result, it will be much easier to cast iron than steel as it is easily poured when melted and does not shrink.

Cast iron is also cheaper as the required labour and material cost is lower than that of cast steel (Stainless Steel Casting VS Cast Iron, 2018). As a result of all that was mentioned above, the most suitable material to use for this design project is **cast iron**.

Conceptual Ideas for Design

One of the most important requirements of this project the two-axis motion. The first step so solve this would be to distinguish between all linear systems and decide on one which best suits the requirements. XY-tables allow the horizontal of machines movement over two axes and are widely used in milling machines and drilling machines. These tables can be operated both manually and automatically. In most cases the drive is applied by a hand wheel or linear motor (XY-tables, 2022).

The diagram alongside is an application of a XY-table. As you can see the two endplates are connected by multiple rods. The leadscrew runs perpendicular to the driver or hand wheel and through a solid plate which acts as sliders. Two identical rods are attached to the endplates which provide the table with a two axis horizontal motion.

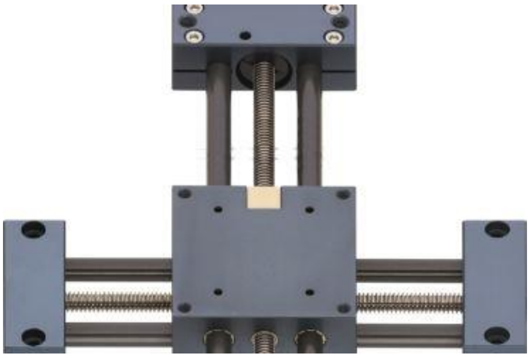

Figure 3: XY-Table

In this case I will design a table in Inventor using the set of axes shown in figure 4. Therefore, the idea is to have a left to right motion along the x-axis and a front to back motion along the z-axis.

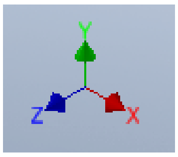

Figure 4: Three dimensional Cartesian Plane

Another concept that will contribute to an efficient and accurate design is the top plates surface design. A highly efficient option is the T-slot design (Image 3 in Figure 5). This concept will be beneficial for clamping kits and T-nuts, which are available anywhere and are reasonable cheap. A good clamping system will ensure precision during the milling process.

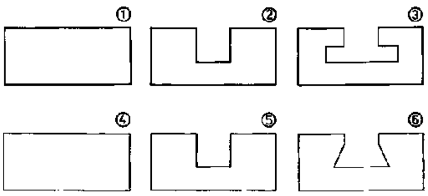

Figure 5: Different types of Milling Grooves.

Calculations

<u>Force in the worst case scenario</u>

We know:

$$r_{tool} = 15\ mm$$
$$rpm = 4000$$
$$Power\ (H) = 10\ kw$$

$$H = T\omega$$

$$\therefore T = \frac{H}{\omega}$$

$$= \frac{10\text{x}10^3}{4000\left(\frac{2\pi}{60}\right)}$$

$$= 23.87\ Nm$$

Now,

$$F = \frac{T}{r} \qquad \because T = F\ \text{x}\ r$$

$$= \frac{23.87}{15\text{x}10^{-3}}$$

$$= 1591.55\ N$$

If we examine a 100kg load:

Thrust force

$$F = Mg$$

$$= (100)(9.81)$$

$$= 981\ N$$

For cast iron, the coefficient of kinetic friction is:

Cast iron on cast iron -clean and dry – $\mu = 0.15$

Cast Iron on cast iron – lubricated and greasy – $\mu = 0.07$

(The Engineering Toolbox – Friction Coefficients, 2022)

A machine table will last much longer and perform better with lubrication applied to it.

Therefore, I will use a coefficient of kinetic friction of 0.07 in my calculations.

Frictional force $F_N = M_{load\ \&\ table}g$

$$= (100 + 220.348)(9.81)$$

$$= 3\ 142.61\ N$$

$$F_f = \mu F_N$$

$$= (0.07)(3142.61)$$

$$= 220\ N$$

The total force acting on the table due to movement (with load)

$$F_T = F + F_f$$

$$= (981 + 220)$$

$$= 1\ 201\ N$$

Cost Analysis

The average cost of iron casting is **R25/kg** (Simple Cast Iron Price, 2022). Multiplying the components weight calculated by Inventor by the price we get:

<u>Base</u>

$$\begin{aligned} Cost &= Mass\ x\ Price\ per\ kg \\ &= (56.966)(25) \\ &= \pm R1424.00 \end{aligned}$$

<u>Top Plate</u>

$$\begin{aligned} Cost &= Mass\ x\ Price\ per\ kg \\ &= (74.962)(25) \\ &= \pm R1874.05 \end{aligned}$$

<u>End Plate x 4</u>

$$\begin{aligned} Cost &= Mass\ x\ Price\ per\ kg \\ &= (10.597)(25) \text{ x } 4 \\ &= \pm R1059.70 \end{aligned}$$

<u>Rod x 4</u>

$$\begin{aligned} Cost &= Mass\ x\ Price\ per\ kg \\ &= (2.457)(25) \text{ x } 4 \\ &= \pm R245.70 \end{aligned}$$

<u>X-Slider x 2</u>

$$\begin{aligned} Cost &= Mass\ x\ Price\ per\ kg \\ &= (9.247)(25) \text{ x } 2 \\ &= \pm R462.36 \end{aligned}$$

<u>Z-Slider x 2</u>

$$\begin{aligned} Cost &= Mass\ x\ Price\ per\ kg \\ &= (5.872)(25) \text{ x } 2 \\ &= \pm R293.6 \end{aligned}$$

<u>Leadscrew x 2</u>

$$\begin{aligned} Cost &= Mass\ x\ Price\ per\ kg \\ &= (2.983)(25) \text{ x } 2 \\ &= \pm R149.16 \end{aligned}$$

TOTAL COST: **R5 508.56**

Conclusion

This report reflects all the steps that were taken to towards the final design of the machine tool table. Throughout the report I explained why certain decisions were made to give the reader a clear understanding of where I was coming from.

Standard parts were used where possible to narrow down the cost of the table and to ease the manufacturing process. Using standard parts where possible is beneficial as they are easily to replace if worn or damaged. The main components of the tool table were designed by me, using Inventor, to meet all the design requirements.

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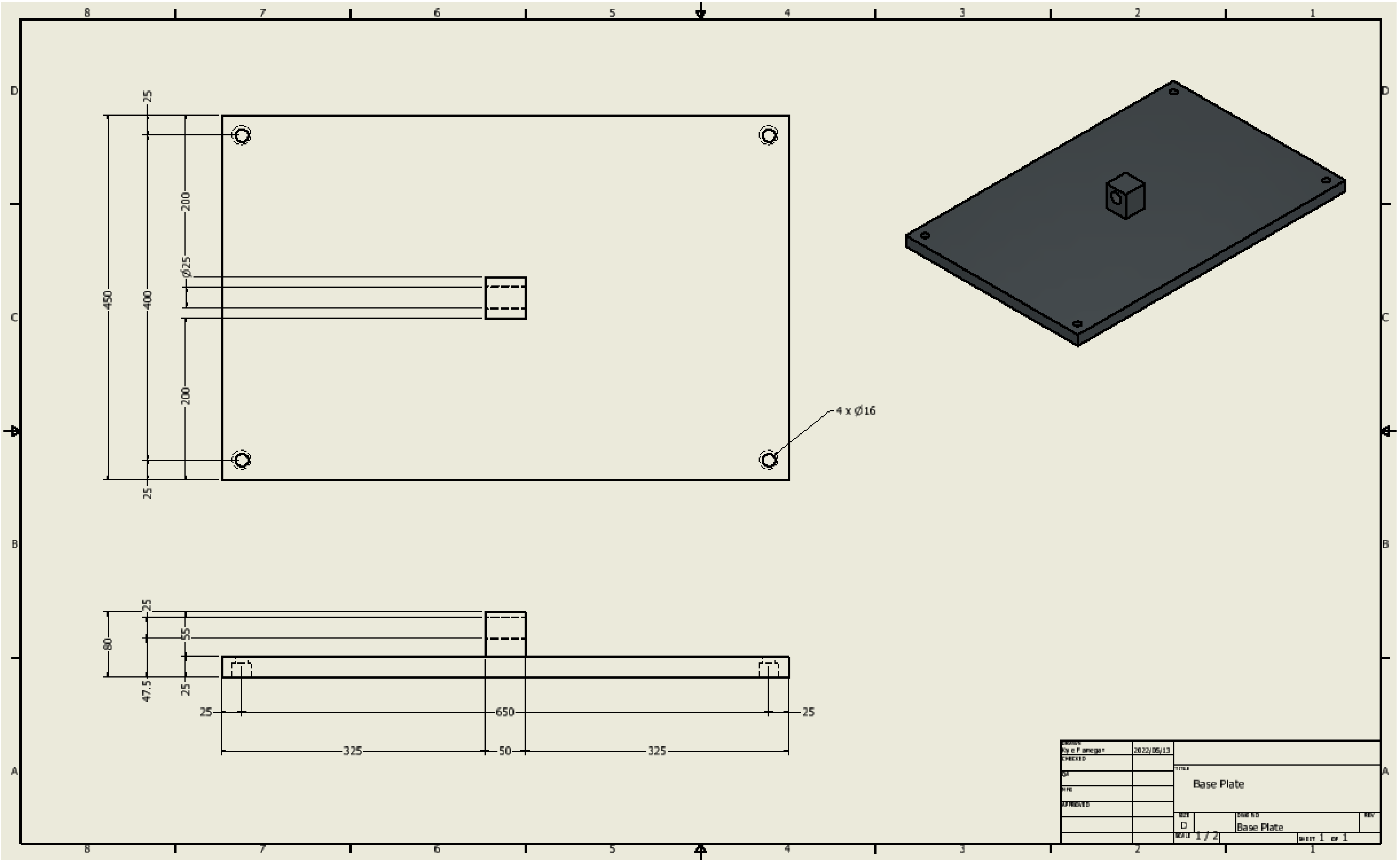
Appendices



25
200
Ø25
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400
200
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4 x Ø16
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55
80
47.5
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25
650
25
325
50
325
2022/05/13
CHECKED
Base Plate
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Base Plate
1 / 2
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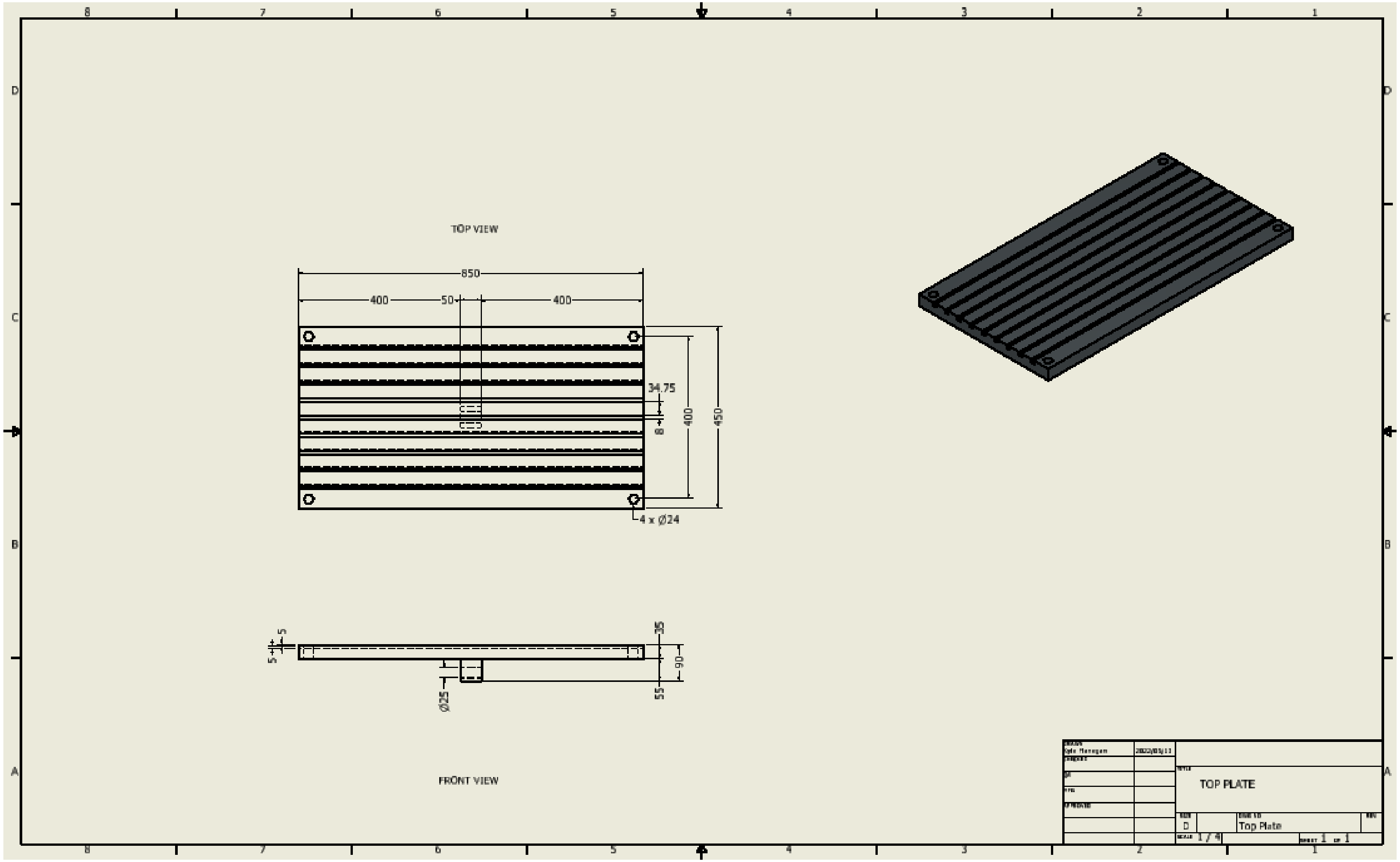
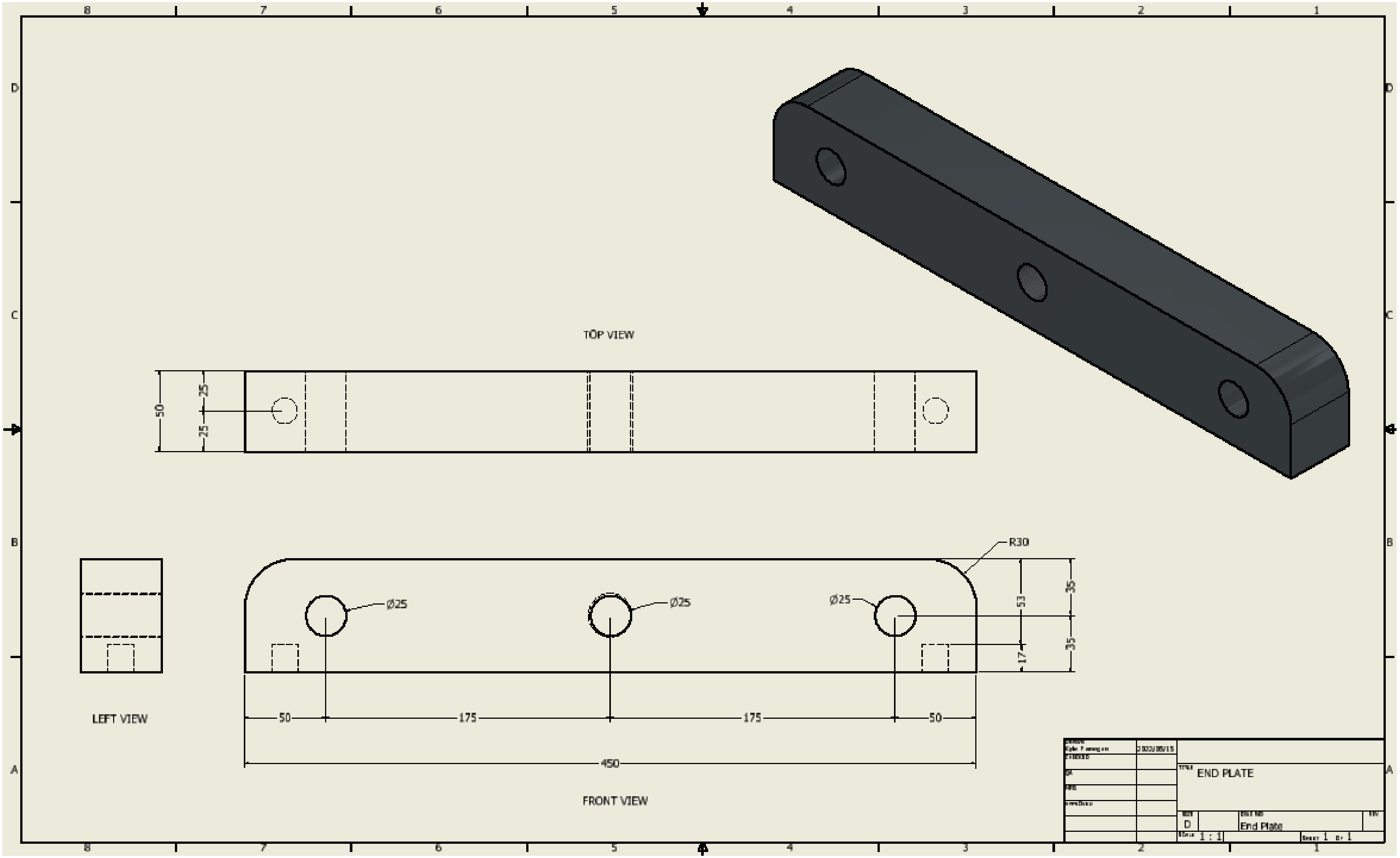
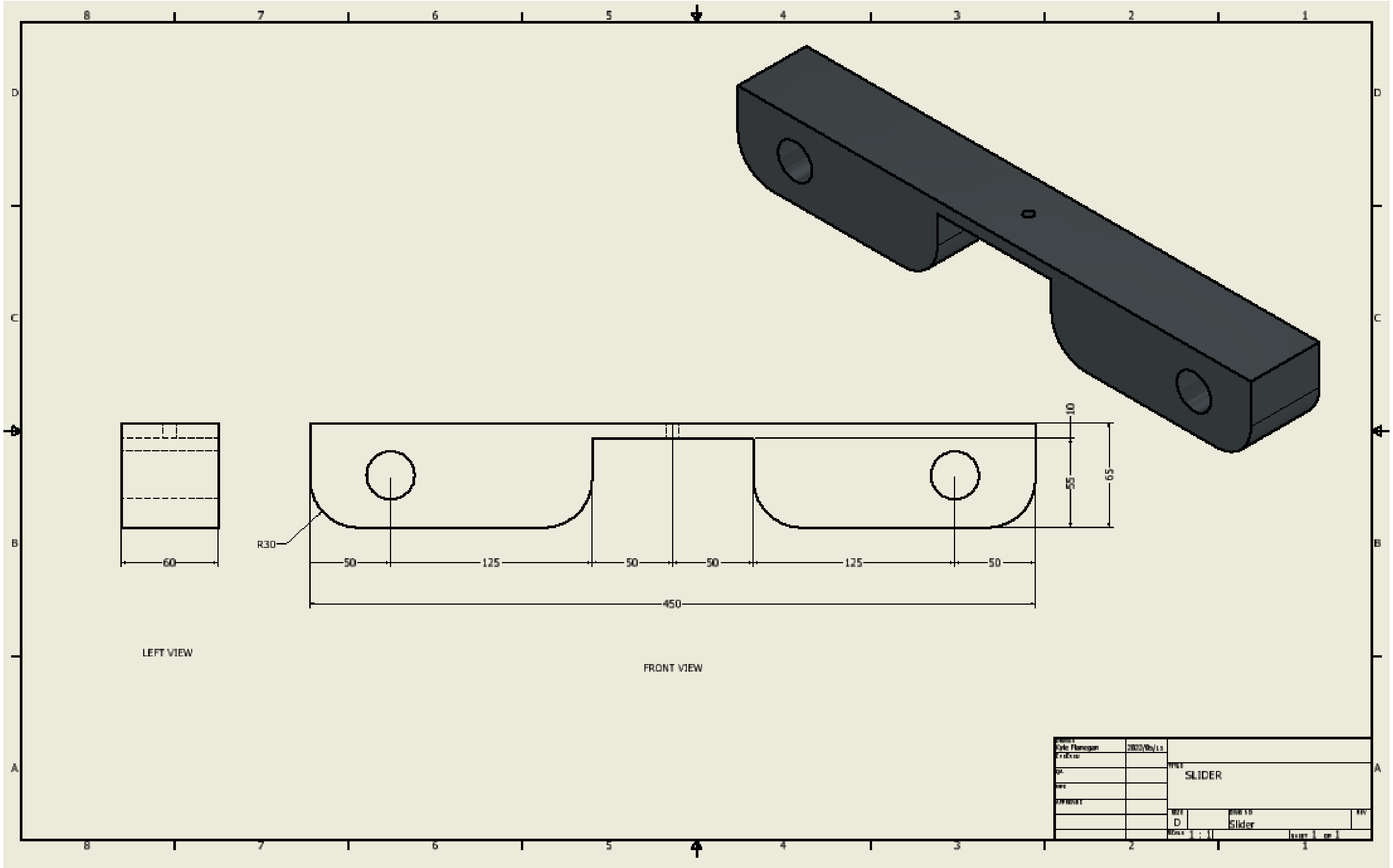
1

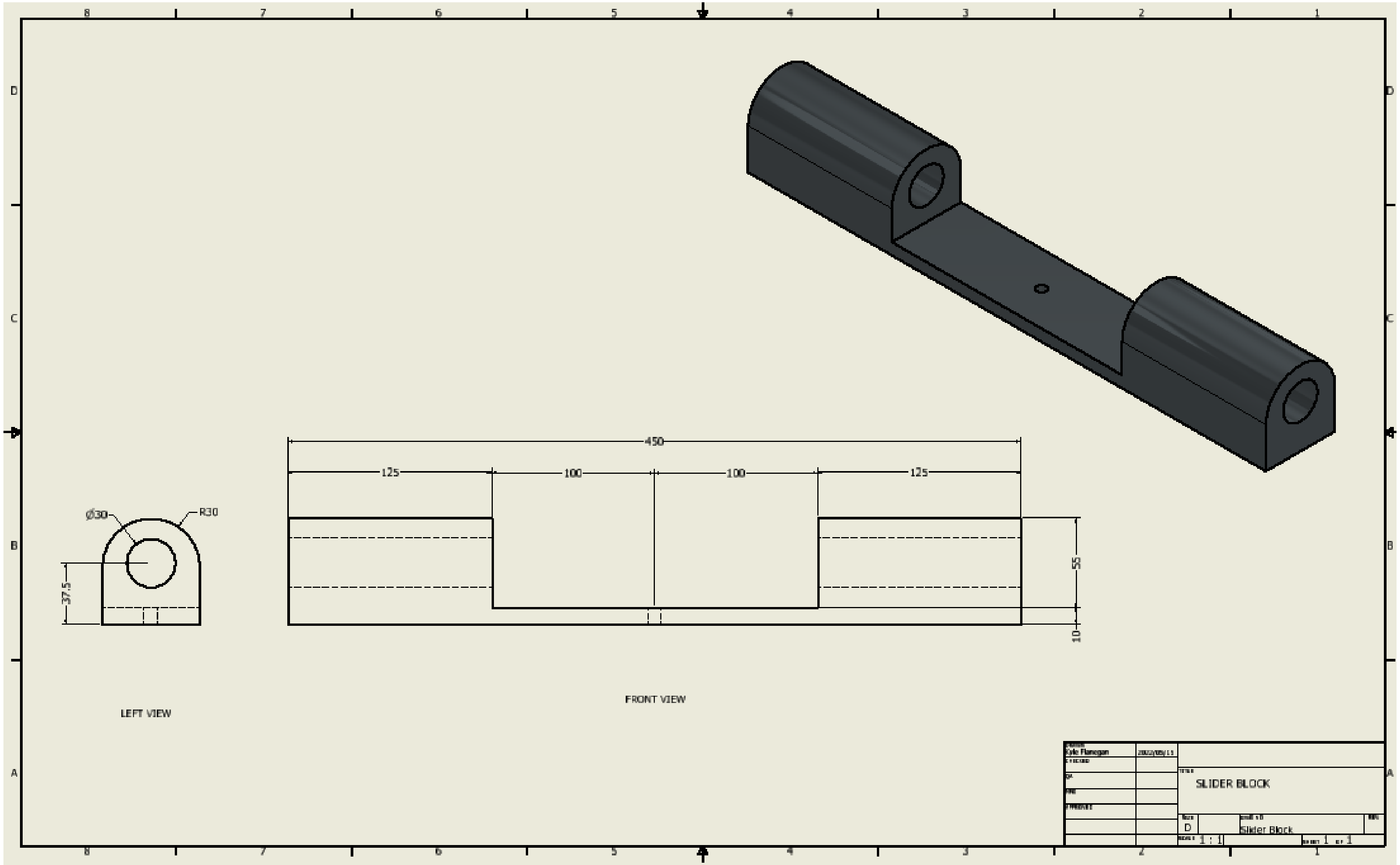


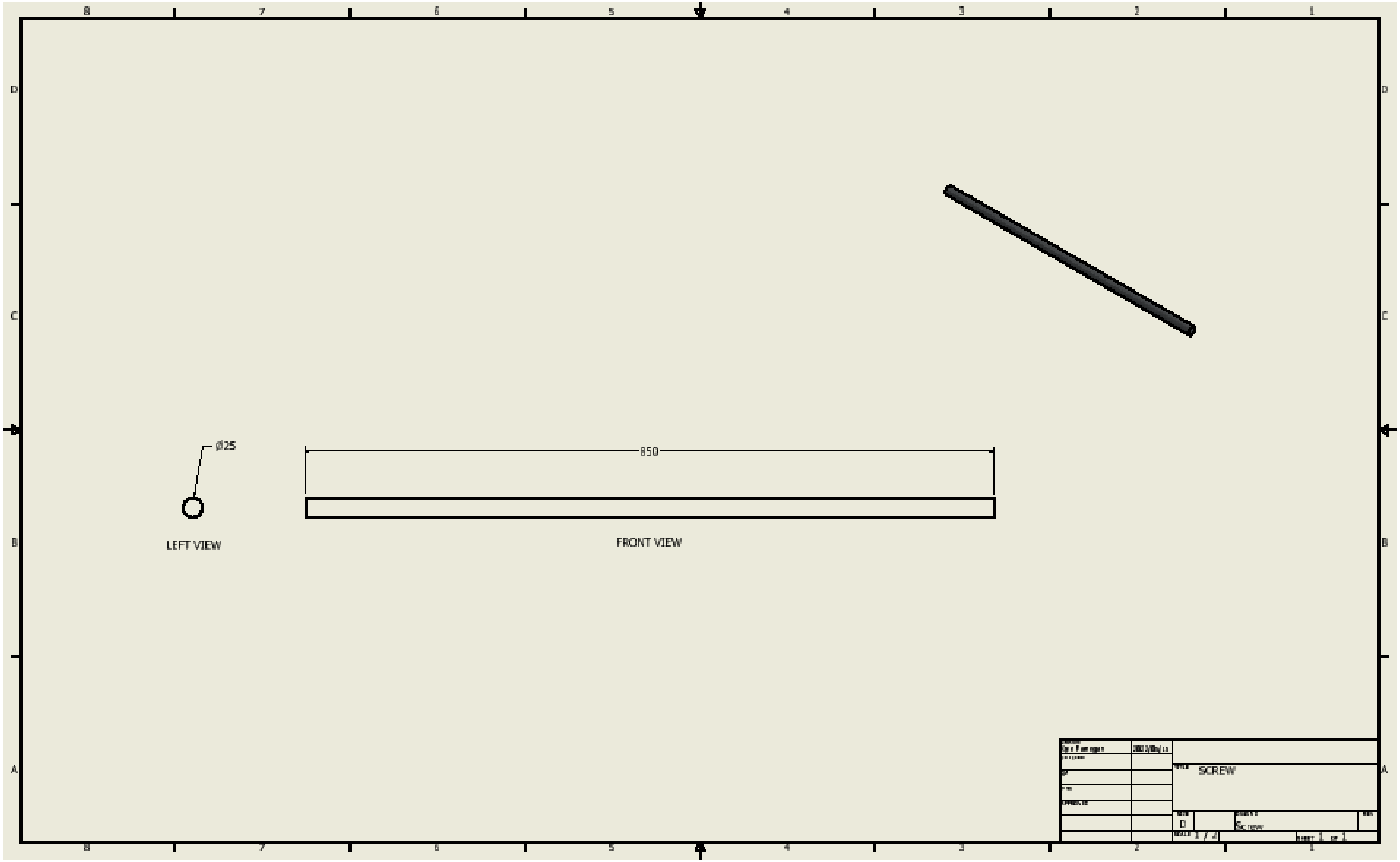
TOP VIEW
850
400
50
400
34.75
8
400
450
4 x Ø24
5
5
35
90
55
Ø25
FRONT VIEW
TOP PLATE
D
Top Plate
1 / 4
1
1



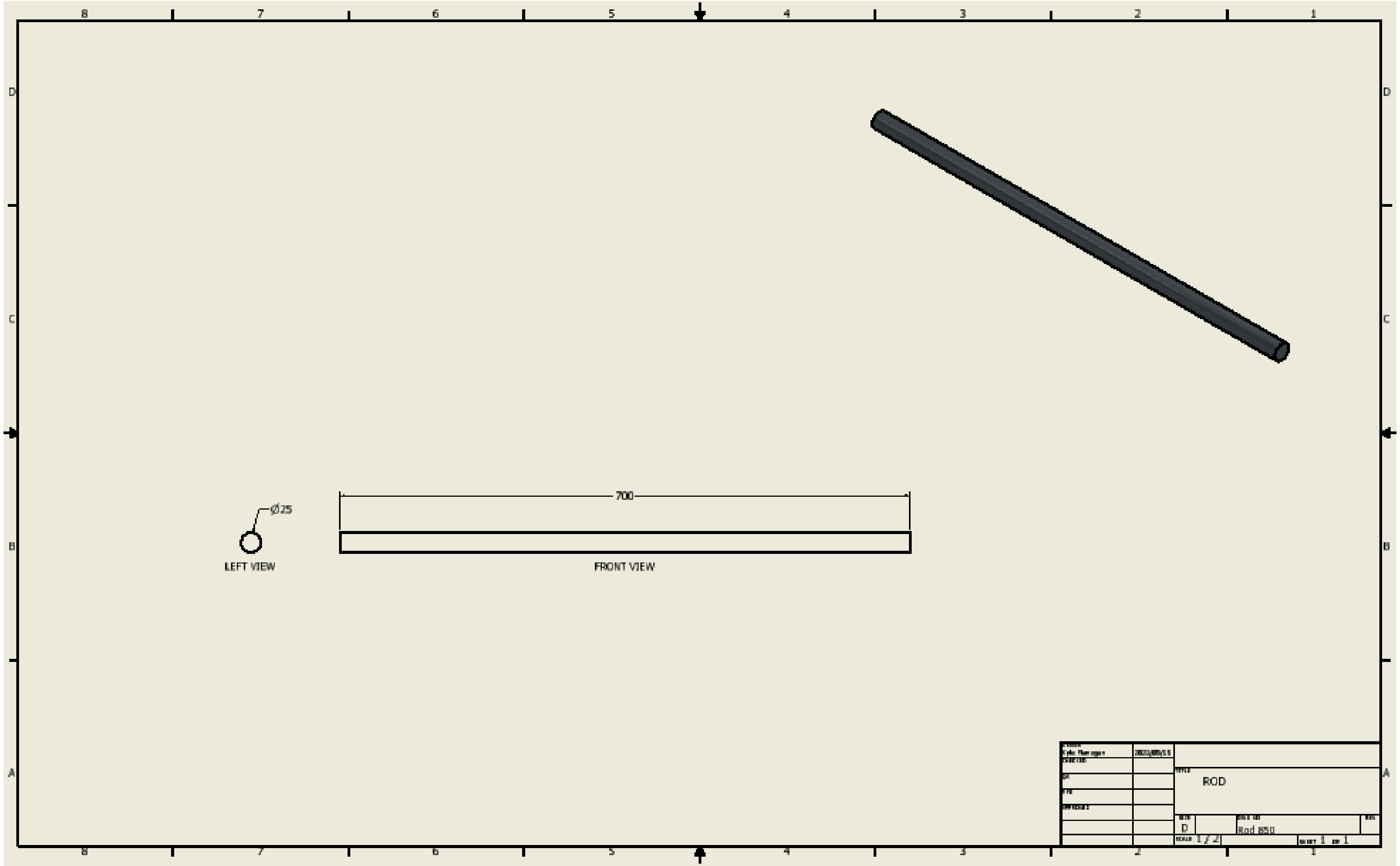
TOP VIEW
50
25
25
R30
Ø25
Ø25
Ø25
35
53
35
17
50
175
175
50
450
LEFT VIEW
FRONT VIEW
END PLATE
D
End Plate
1 : 1
1
1


LEFT VIEW
FRONT VIEW
60
R30
50
125
50
50
125
50
450
10
55
65
Kyle Flanegan
SLIDER
D
Slider
1 : 1

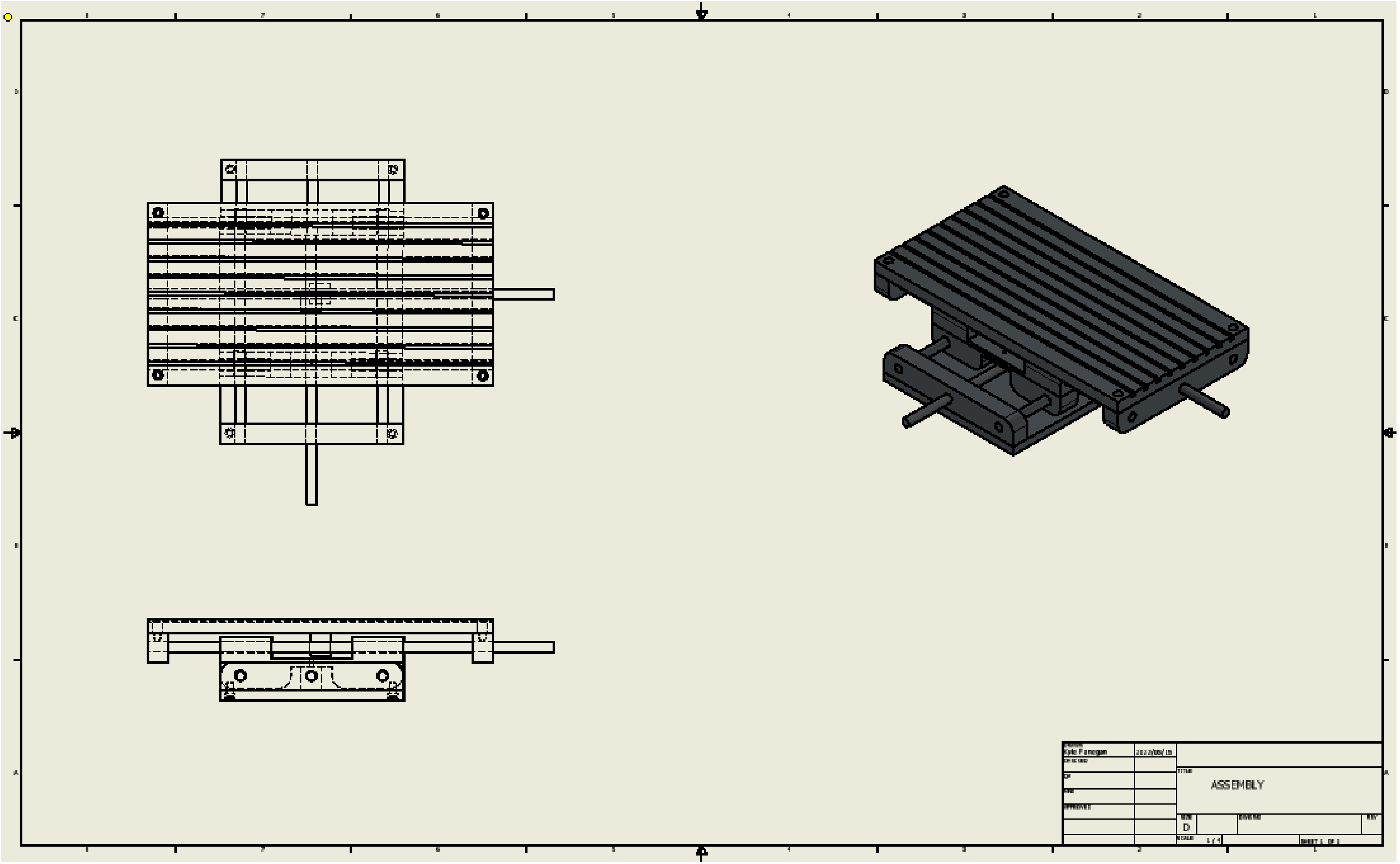

450
125
100
100
125
55
10
Ø30
R30
37.5
LEFT VIEW
FRONT VIEW
Kyle Flanegan
SLIDER BLOCK
D
Slider Block
1 : 1
1 of 1



Ø25
850
LEFT VIEW
FRONT VIEW
SCREW
D
Screw



700
Ø25
LEFT VIEW
FRONT VIEW
ROD
D
Rod 850
1 / 2
SHEET 1 OF 1



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ASSEMBLY
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