1/10/2020

Machine Design II (MMDV202)

Mould Design Project

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Plagiarism declaration

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Student Surname Kyle Flanegan

Signature: Flanegan

Date: 12 / 01 / 2021

Mark Sheet

Machine Design (MMD2112)

MOULD DESIGN PROJECT

Assessment Criteria

N	Criteria	Mark allocation, %	Mark, %
1	*Choice of plastic parts*		
	1.1 Complexity	5	
	1.2 Drawings of plastic part	5	
	1.3 Specifications and description of plastic part	5	
	Sub-Total	**15**	
2	*Mould design ideas*		
	2.1 Comprehensive literature survey	5	
	2.2 Discussion of few conceptual designs	5	
	2.3 Justification of final design	10	
	Sub-Total	**20**	
3	*Analysis and specifications of designed mould*		
	3.1 Engineering analysis & re-design	10	
	3.2 Selection of standard mould parts	10	
	3.3 Manufacturing aspects of non-standard parts	10	
	3.4 Final acceptance of design (specifications)	10	
	Sub-Total	**40**	
4	*Report*		
	4.1 Assembly drawings	5	
	4.2 Part drawings	10	
	4.3 Written report neatness	5	
	Sub-Total	**20**	
5	*Project Presentation (5 min, all members)*	**5**	
6	*Peer assessment (per student)*	Loss of marks of a student will result in proportional reduction in the total project mark for that particular student (the rest of members will not be affected)	(-1) x (loss of marks x 10)
		In case of deviation in peer assessment, marks are indicated separately for each member →	Names
		Deducted marks →	
	Total	Total (100)	

Comments____

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Lecturer_________________________ Date:______________________

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Introduction

Building and creating LEGO objects is a fun activity that has become very popular over the years. In this day and age, it is required of factories, companies etc. to keep up with their customer's needs and wants. Plastic injection moulding is a highly efficient way to produce large amounts of plastic objects in a short space of time. This low labour cost invention is being used by many supply factories around the world. The objective of this project is to design a mould that would be used to produce a certain object, specifically a LEGO brick in my case.

Choice of Plastic Parts

Specifications and Description of Plastic Part:

Every LEGO ever made is built to fit perfectly with every LEGO ever made. LEGO runs size **tolerances of .0005** with extremely low variations. The mould that I am going to be designing will produce a LEGO piece called the BRICK 2X4. This particular piece has eight studs on the top of the brick. It has a cavity beneath it with 3 cylinders which ensure that all LEGO pieces join perfectly together. It is very smooth and shiny on the outside and has very sharp corners. The specific piece that I will be producing is a very commonly used piece in the making of LEGO objects.

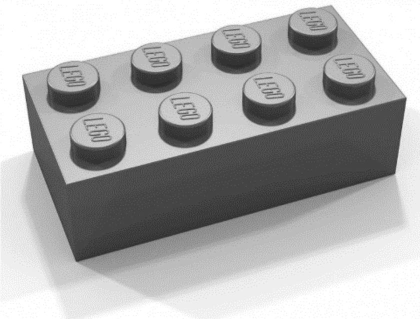


Figure 1: 8 Stud Lego Brick

Dimensions of Plastic Part:

Measurement	Dimension (mm)
Total Length of Block	32
Total Width of Block	16
Total Height of Block (including Stud height)	11
Stud Height	2
Stud Diameter	5

Mould Design Ideas

Comprehensive Literature Survey:

Plastic injection moulding is a process used around the world to produce plastic parts and components. It is one of the key methods of production of processing plastics. Production factories strive to produce products at a low cost, to meet the requirements of the customers. Injection moulding is one of the most cost-effective forms of plastic production. The injection moulding machine has two units, the injection unit, where plastic is melted, and the clamping unit, where you will find the mould. The process includes a few steps to produce the final plastic object. Plastic pellets are fed into the plasticizing unit of the injection moulding machine whereby they are melted by heaters. It is then passed through a cylinder via a single screw extruder with a one-way valve. This melted plastic is then injected into the mould, which has two parts such as the core and cavity, through a nozzle. The core shapes the melted plastic once it is injected. Lastly, the plastic is cooled until it is ready to be taken out of the mould. The core and the cavity of the mould is then separated by the machine and the required plastic part is removed. Many factories do all sorts of tests (such as hardening) on the final product until they are satisfied that the part is ready for use. The most common plastic materials used in an injection mould machine are Acrylonitrile Butadiene Styrene (ABS), which is used to make LEGO block, High Impact Polystyrene (HIPS), which is generally used to make toolboxes, Polypropylene (PP), which is widely used in the food storage and packaging industry.

Discussion of a few Conceptual Designs:

The most important thing to consider when designing a mould for a plastic part is the dimensions of that part. If there are any incorrect dimensions in your mould design, it will not produce the desired plastic product. The melted plastic is going to be fed through the runners and gates and eventually take the shape of the plastic part between the core and cavity. I will be using a gate measurement of 5mm thick as that is one of the standards for plastic injection moulding. Another important design that needs very high accuracy is the ejector system. The ejector system I am going to use is one where an ejector bar pushes the ejector retainer plate to force the ejector pin sleeves to press against the hardened plastic and pop it off of the mould. This will be the most effective way in which the plastic parts could be removed from the mould. This means that I will need to create a hole in the centre of the ejector plate which is the same dimension of the ejector bar. The bar will then penetrate through the ejector plate and push the ejector retainer plate forward. The ejector pin sleeves will be guided by the ejector pins, which will remain stationery because they form part of the mould itself, until they reach the hardened plastic to free it from the core.

Justification of Final Design:

After discussing a few conceptual designs that I have to think about before I design my mould, I have a good idea as to how the mould process will undergo. I will be designing my mould in Inventor manually without using the mould design feature as I believe it is easier and more efficient for the specific plastic part that it will produce.

The molten plastic mould will successfully inject from the sprue through the locating ring, which will then travel through the runners.

Once the plastic reaches the gates at each cavity, the plastic will filter between the cavity and mould to take their shape and form the plastic LEGO piece.

I will design the injector system slightly different to a normal mould where the ejector pins slide up to push the plastic piece off of the mould.

In my mould's ejector system, the ejector bar will slide through an opening in the ejector plate (the plate above the bottom plate). The bar will then push the ejector retainer plate which will force the ejector pin sleeves to slide along the pins. Once the sleeves reach the hardened plastic, the force will then push the LEGO blocks off the mould core.

The ejection mould process will then repeat itself until the required number of plastic LEGO pieces are produced.

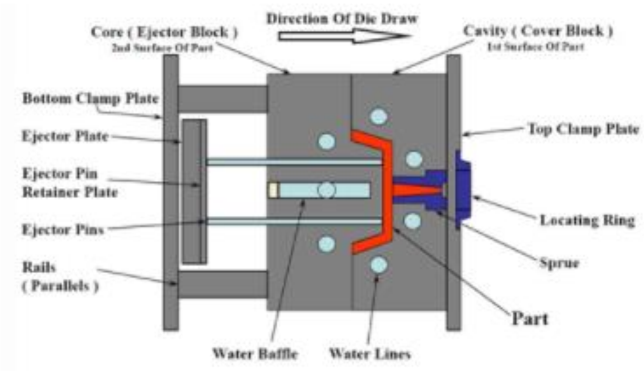
There may be a few restrictions in designing the mould for the LEGO brick such as the sharp edges and corners that the plastic piece has. In the process of injection moulding, it is not preferable to have sharp corners and edges, however the LEGO brick has to be sharp edged. Another restriction may be the difficultly of the molten plastic to reach the small extrusions in the cavity to form the studs on the top of the block.

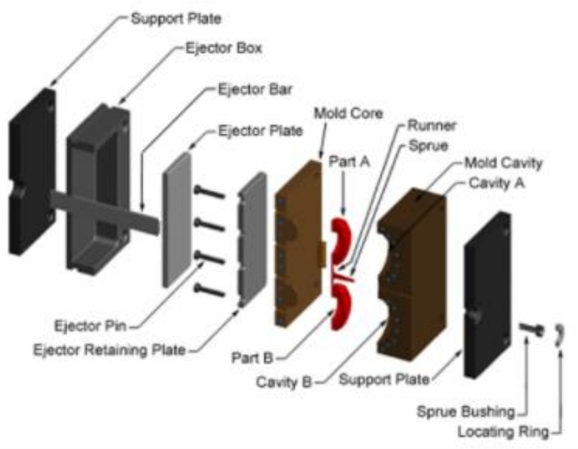
Despite these restrictions, which you will always occur in the design process, the mould that I am designing will successfully produce the desired plastic part that I have discussed previously, the 2X4 LEGO brick.

Analysis and Specifications of Designed Mould

Selection of Standard Mould Parts:

The injection mould is made of a series of parts that help form the molten plastic into its shape. Without the mould there will be no final plastic object. As I explained previously, I am going to manually design my mould, so I will briefly describe the parts that I have chosen to include and their function. The detailed diagram below shows the main components that are involved in the design of the plastic injection mould.





Mould Core

Part of the mould with the inner shape of the part which helps to shape the melted plastic into the final product.

Mould Cavity

The molten plastic enters the cavities to form the shape of the desired part. This is the area of the mould that has the outer shape of the product.

Guide Pins

These pins help the core and cavity mould hold their alignment when pushed together to form the final part.

Top Plate and back plate

This plate is located at the top of the mould, with the sprue bushing in the centre. The guide pins are penetrated through the plate on each of the four corners to hold the core and cavity aligned perfectly. The back plate is located at the bottom of the mould and is there to hold all the parts of the mould together along with the top plate. All the parts are found between the top and back plate.

Nozzle/Sprue Brush

The molten plastic enters the mould through the nozzle of the barrel of the moulding machine. The nozzle sits against the sprue brush which helps centre the nozzle to the mould.

Runners and Gate

These are the paths made in the mould to ensure the plastic melt gets to the cavity. The gate is the part between the runners and the mould. Once the plastic shape has been made, the runner plastic gets thrown away as it serves no purpose to the part.

Cooling System

Cooling channels are inserted in the mould cavity where the cool water passes. This passing of cool water lowers the temperature of the melt and solidifies it to form the plastic part. These channels are made by drilling into the core or cavity.

Ejector System

The ejector pins help to remove the plastic product once it has cooled inside the mould cavity. They are mounted to an ejector plate. The forward motion of the ejector plate forces the pins to push the plastic part off of the mould.

Support blocks

There are two support blocks which are a rectangular shaped. These blocks guide the movement of the ejector plate. Their height needs to be long enough for the ejector pins to stay hidden from the mould, this length is known as the ejector gap. Once the mould is cooled, the ejector plate will slide up, guided by the support blocks, and the pins will push the part off of the mould.

Engineering Analysis & Re-design:

Manufacturing Aspects

All my designs and drawings were performed in AutoCAD Inventor. There are two ways which a mould can be designed in Inventor; By using the core/cavity function and the other being manual extrusions, both of which will give you your specific mould to produce your plastic part. I went with option two because it is a lot simpler for the plastic part that I want to produce. As we know, every moulding machine is different, which means the mould you make needs to be suited for the machine that you will be using to produce your plastic part. By designing the mould with manual extrusions, I can be sure to use the standard specifications and dimensions needed to make a mould that would fit the LEGO moulding machines perfectly. There are three parts to the process of making a mould for a product; First you have to design the product, then you design the parts of the mould, and lastly the design of the mould. As explained before, the main parts of the mould are the core and the cavity, which depend entirely on the shape of the final product.

The Cavity includes:

- Injection point for the plastic melt.
- Runners and gates
- The upper part of the LEGO block with the eight studs

The Core includes:

- The bottom of the LEGO block with the three hollow cylinders

Once these two pieces (the core and cavity) come together, guided by the guide pins, they leave a gap between the two which the plastic melt fills up to create the final piece. Once the plastic is cooled, the ejector pins push against the piece to remove it from the mould.

Due to the fact that I am required to produce 100 000 units of my plastic part, I decided to include 4 core and cavities so that my production rate is four times faster. i.e., for every cycle of the injection moulding process, the mould would make 4 LEGO blocks.

The most important thing to keep in mind when designing the core and cavity is the size of the product. The core of the mound is made smaller than the cavity. The difference between the two sizes is ultimately the thickness of the plastic product (in this case 1.5mm).

Design of the Product

A simple sketch of a rectangle using the standard dimensions (32 x 16mm) of an 8 stud LEGO block was extruded it to the correct height (9mm). On top of the extrusion, I created another sketch of the 8 studs, correctly spaced out with standard dimensions and extruded them to their specific height (2mm) as shown in figure 3.

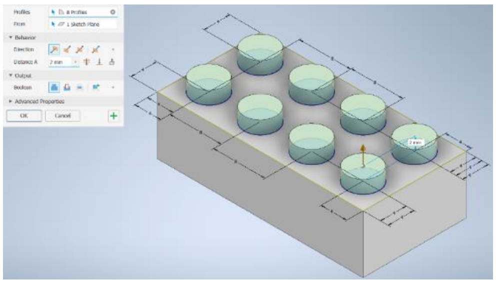


Figure 2: Extrusion for the 8 studs

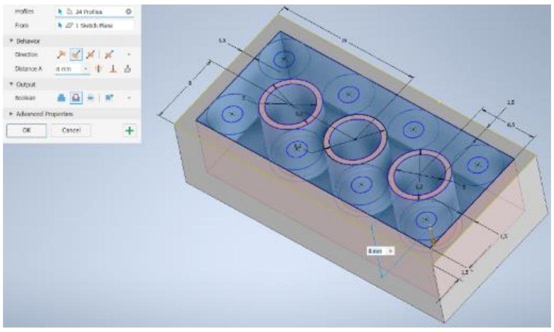


Figure 3: Extrusion to create the cavity beneath the block

The third extrusion was made inwards to create the cavities beneath the block (Figure 4). Lastly, I checked that all the holes and studs' line up perfectly and flush for any standard LEGO block to join. The drawing was made by placing the necessary views and dimensions.

Design of the Parts of the Mould

Designing the cavity was fairly simple and straight forward, the dimensions were exactly the same as the entire outside dimensions of the plastic part. Firstly, I created a plate with the dimensions; 150 x 150 x 20, which was a standard plate size for a plastic injection moulding machine.

The extrusion of the cavity came from a sketch that I made of the surface of the 150 x 150 face of the plate. I extruded the 4 cavities inwards by 9 mm as that was the outside dimension of the block, excluding the Studs.

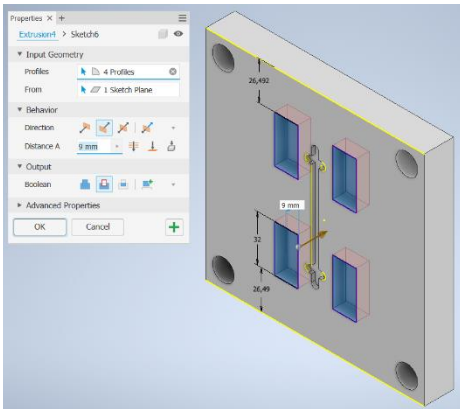


Figure 4: Extrusion of Cavity

The next sketch performed was to produce the 8 Studs on the surface of the LEGO block as shown in figure 6. They had a diameter of 5 mm and a height of 2 mm. I performed the sketch on top of the previous extrusion of the 4 rectangular cavities.

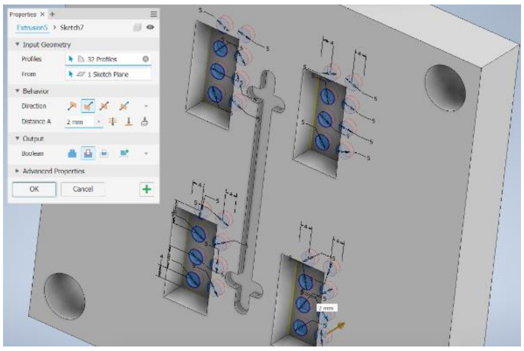


Figure 5: Extrusion of 8 Studs

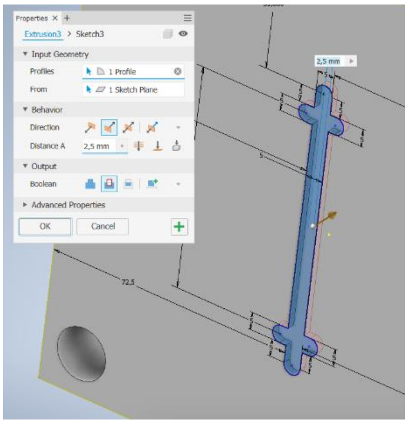


Figure 6: Extrusion of Runners

Lastly, we have the runners (Figure 7). I performed a sketch for the runners on the same face of the plate. The standard runner width/diameter is 5mm, so once the sketch was completed, I extruded it by 2.5 mm inwards. The same extrusions were made for the runners on the core, I did this by copying the sketch from the cavity to make sure that they are exactly the same.

Designing the core is going to consist of an extrusion outwards that will fit into the cavity. Its dimensions are going to be smaller as it needs to shape the thickness of the plastic part.

The block sketch was smaller than that of the cavity by 1.5 mm all around the edges. The extrusion was outward by 8 mm as that was the depth of the hollow underneath the block. To get the 8 studs on the top of the block I copied the sketch from the cavity to ensure 100% accuracy and simply changed the diameter of all the holes to 2mm each and extruded them by 2mm.

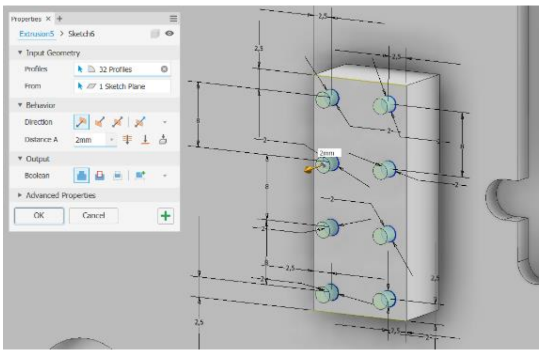


Figure 8: Extrusion of the 8 Studs

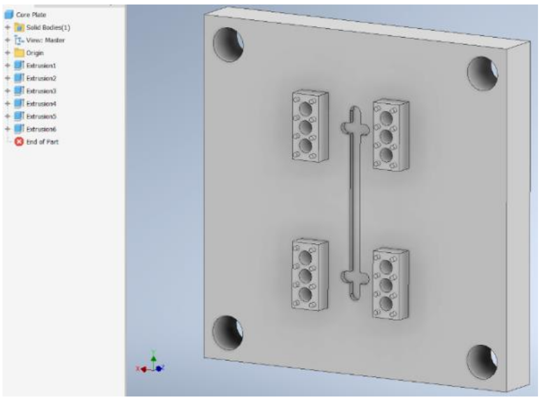
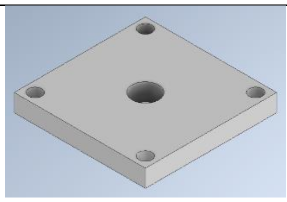
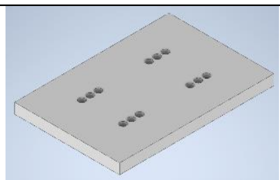
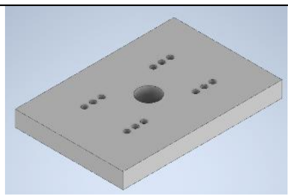
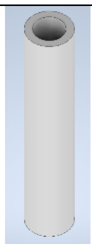
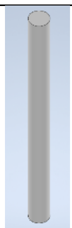
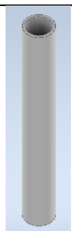
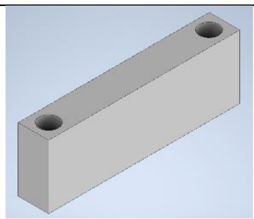
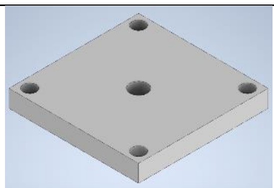


Figure 7: List of Extrusions Performed on the Core Plate

The remaining mould parts were simple and straight forward to design. I used standard mould component dimensions to design them as well as extrusions where necessary to join perfectly with all parts of the mould. Below is a list of the parts and an image of the part design in Inventor:

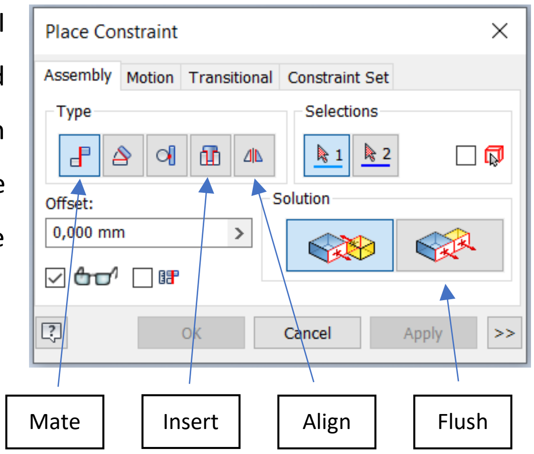
PART	**IMAGE**	**DIMENSION (mm)**
Top Plate		Length – 150 Width – 150 Thickness – 20
Ejector Retainer Plate		Length – 150 Width – 102 Thickness – 10
Ejector Plate		Length – 150 Width – 102 Thickness – 15
Locating Pin		Height – 80 Outside diameter – 15 Inside diameter – 10
Ejector Pin and Sleeve	 	Pin height – 63 Pin diameter – 5 Sleeve height – 50 Sleeve outside diameter – 6.2 Sleeve inside diameter – 5
Support Block		Length – 150 Width – 24 Height - 50
Bottom Plate		Length – 150 Width – 150 Thickness – 20

Final Acceptance of Design (Specifications):

Design of the Mould

Once all of my part drawing were made to their correct dimensions and specifications, the final step was to create an assembly including all of the parts. The assembly took some time to make as I had mate and constrain certain parts in order for them to fit perfectly.

The constrains that I used were mate, flush, insert and symmetry. Mate was used to join two flat surfaces together, while flush was used to align blocks flush together once they had the mate constrain. Insert and symmetry constrains are fairly similar as they both involve holes. I used the insert constrain for the ejector pins and ejector pin sleeves. I simply selected the bottom of the surface of the pin and sleeve as one of the faces and then selected the bottom of the hole in the ejector plate as the second face. The symmetry constraint was very useful to align the necessary centre lines of various holes in different parts.



The top plate has a diameter 30 mm hole in the centre which is allocated for the sprue from the injection mould machine to inject the molten plastic through a one way valve into the mould. The molten plastic travels through the 5 mm hole in the centre of the cavity plate which leads to the runners. The plastic melt will then run through to the 4 gates (one at each cavity) and filter through to take the chape of the core and form the desired plastic part. Once this plastic is cooled by the water running through the cooling channels it will become solid. The mould core and cavity are then separated from each other.

The ejection system plays a vital role in the plastic injection moulding process. I have included an image from a section of the mould assembly to clearly explain the ejection process.

The ejection pins are longer than the ejector pin sleeves as they start at the surface of the bottom plate and end at the height (excluding the studs) of the block on the core. The reason for this is because the pins actually form part of the core mould, they create the three cylinders beneath the LEGO block.

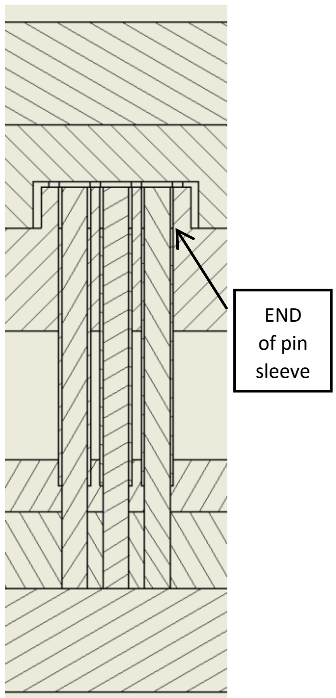


Figure 9: Section Showing Ejector System

The pin sleeves start halfway through the ejector retainer plate and end where the arrow is pointing on the image. Once the ejector bar pushes the ejector retainer plate, the pins will remail stationery, however the pin sleeves will slide along the pins and push the LEGO brick off the core.

Assembly Dimensions:

Total Length	150 mm
Total Width	150 mm
Total Height	130 mm

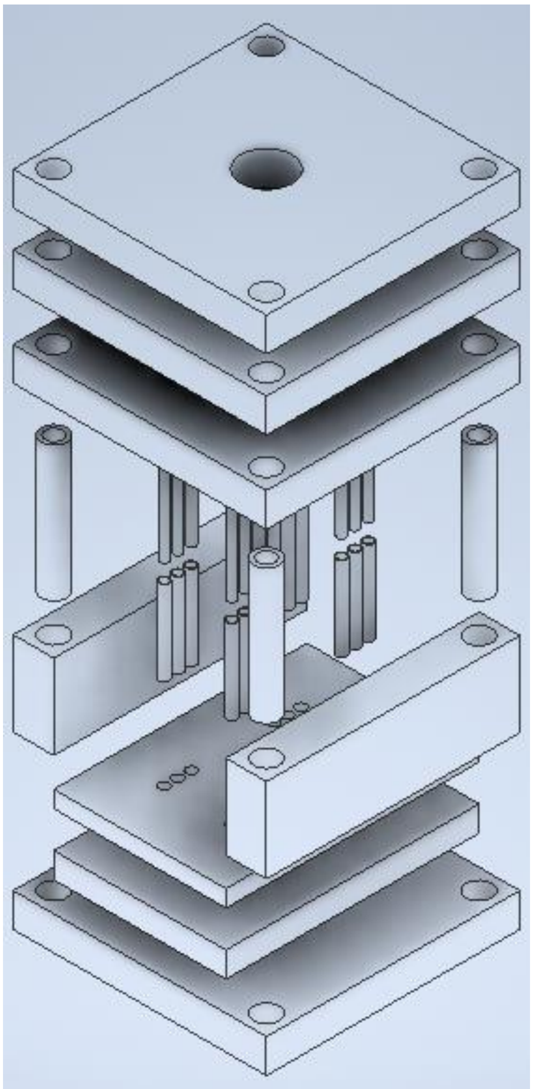


Figure 10: Exploded Assembly of Mould

References

Murray Plastics Team, (2019) LEGOS: The Most Famous Injection Moulded Plastic [online]. [viewed 15 January 2021]. Available from: https://www.murrayplastics.com/blog/legos-the-most-famous-injection-molded-plastic

Chris Williams, (2017) The 10 Best Plastic Injection Moulding Materials [online]. [viewed 18 January 2021]. Available from: https://www.starrapid.com/blog/the-ten-most-popular-plastic-injection-molding-materials/#

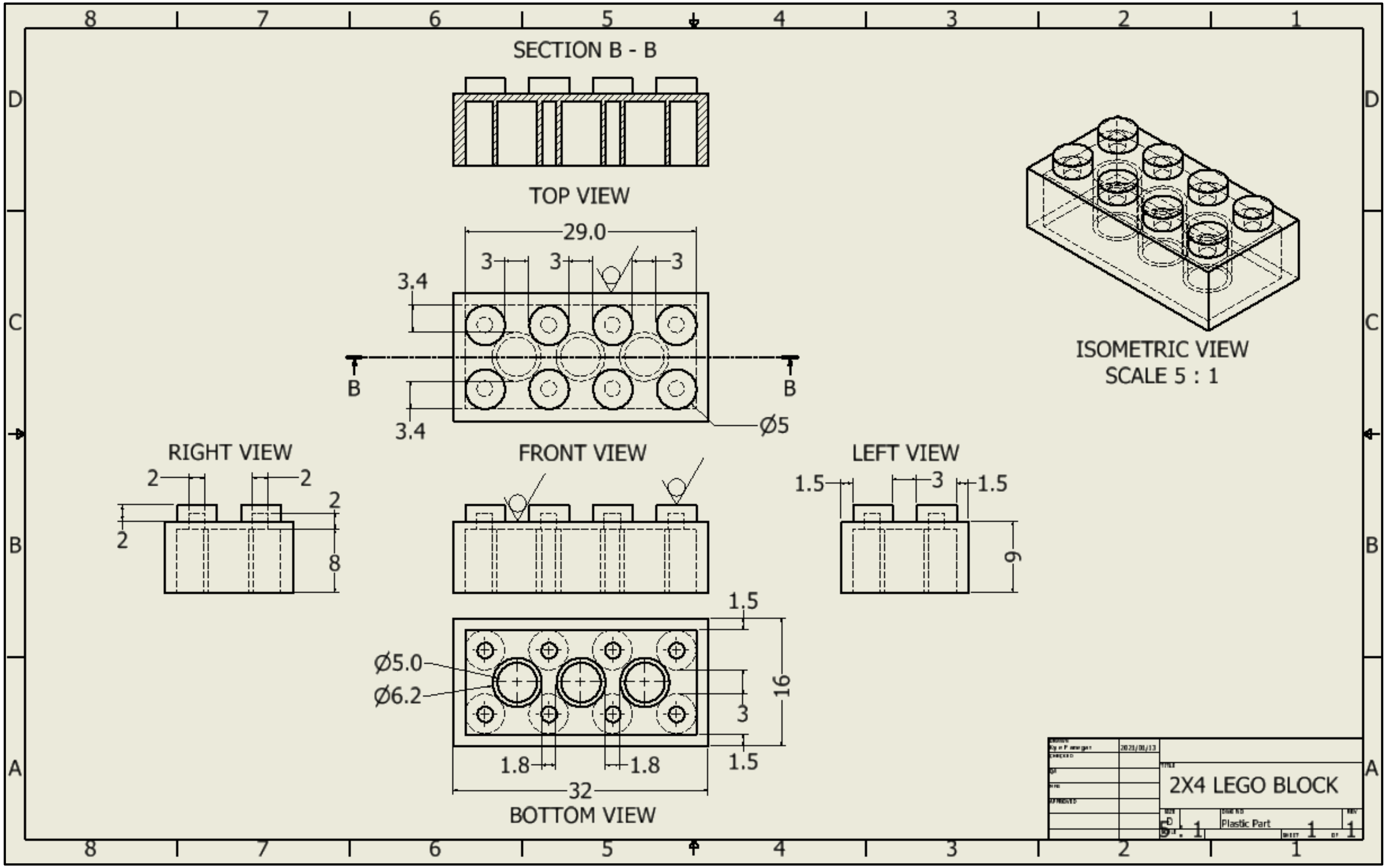
Patty Rasmussen, (2020) Components of an Injection Mould [online]. [viewed 18 January 2021]. Available from: https://news.ewmfg.com/blog/components-of-an-injection-mold

Walsh's Plastic Consulting [online]. [viewed 20 January 2021]. Available from: https://plasticmolddesign.wordpress.com/what-is-a-two-plate-mould/

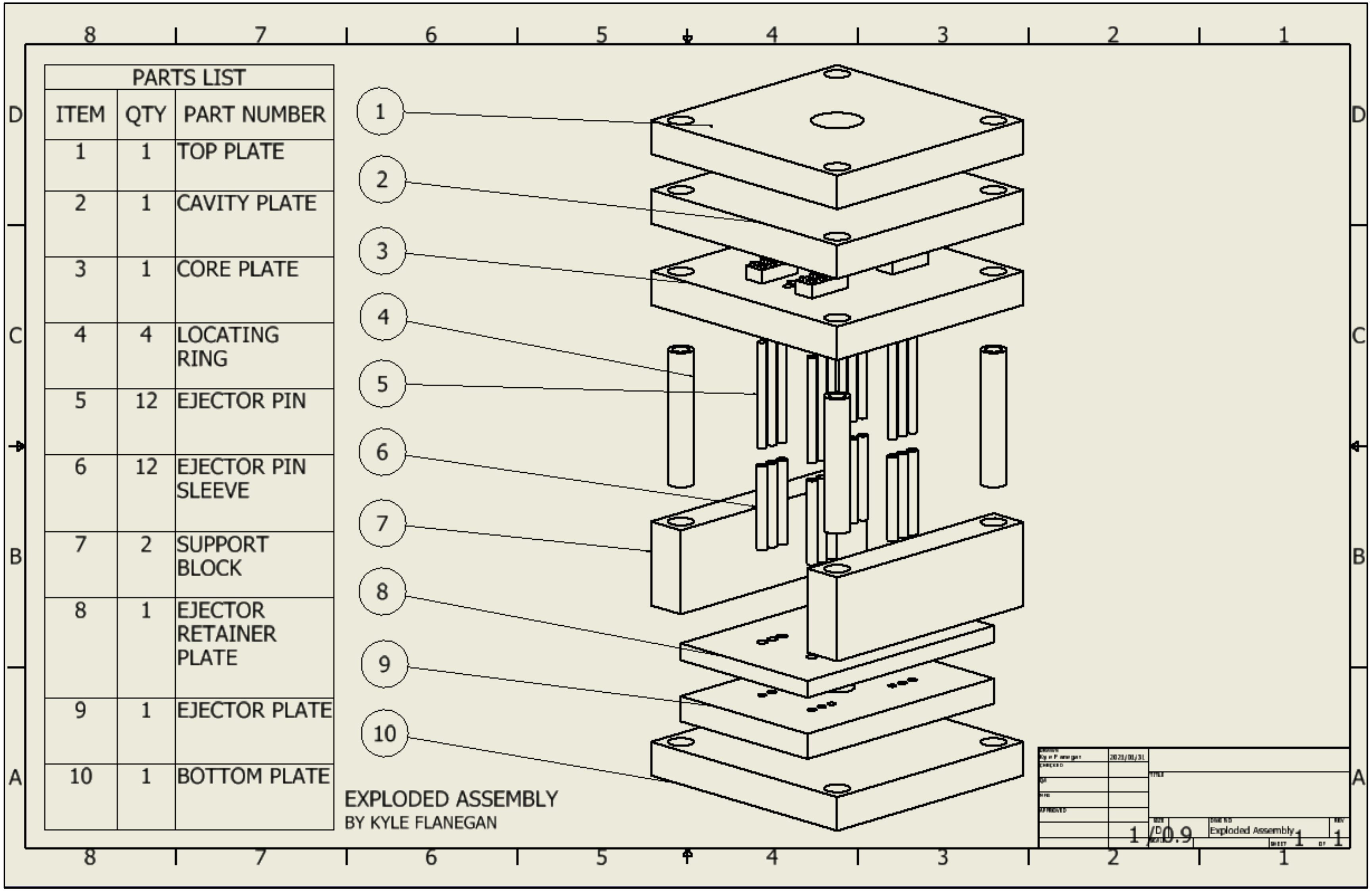
Custompart.net. Injection Moulding [online]. [viewed on 20 January 2021]. Available from: https://www.custompartnet.com/wu/InjectionMolding

ADDENDUM

Drawing of Plastic Part:

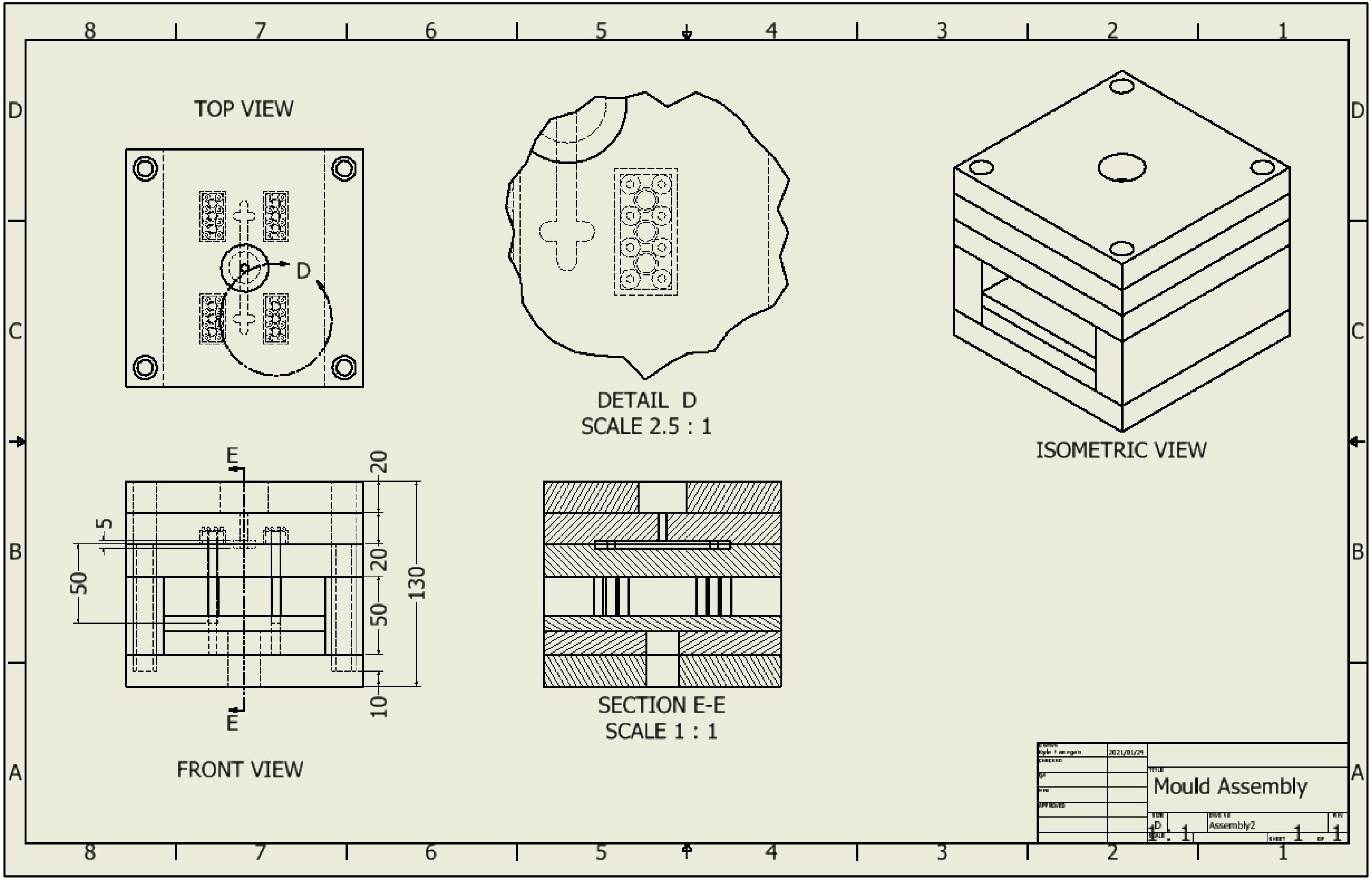


Exploded Assembly Drawing:

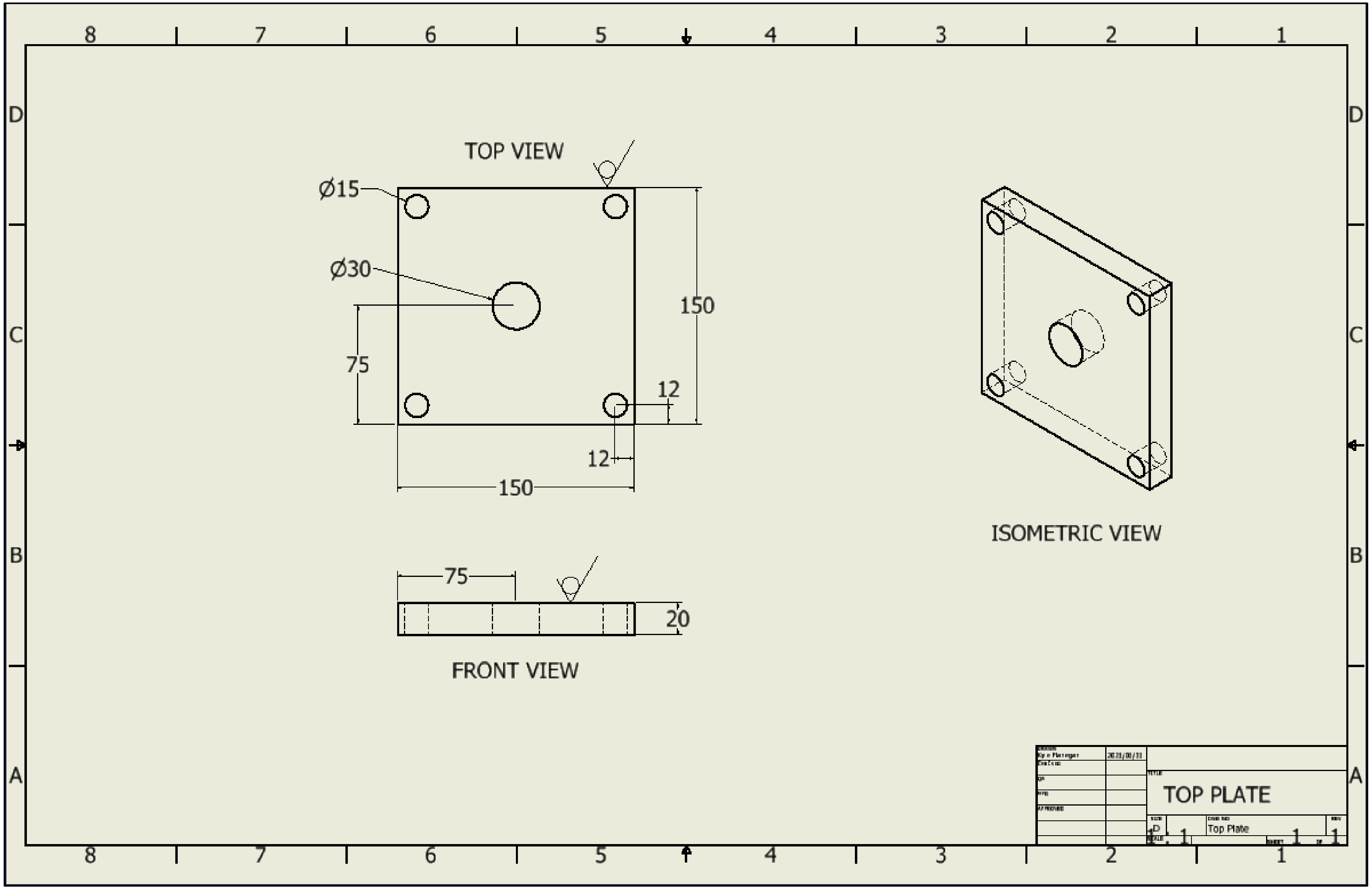


PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	TOP PLATE
2	1	CAVITY PLATE
3	1	CORE PLATE
4	4	LOCATING RING
5	12	EJECTOR PIN
6	12	EJECTOR PIN SLEEVE
7	2	SUPPORT BLOCK
8	1	EJECTOR RETAINER PLATE
9	1	EJECTOR PLATE
10	1	BOTTOM PLATE

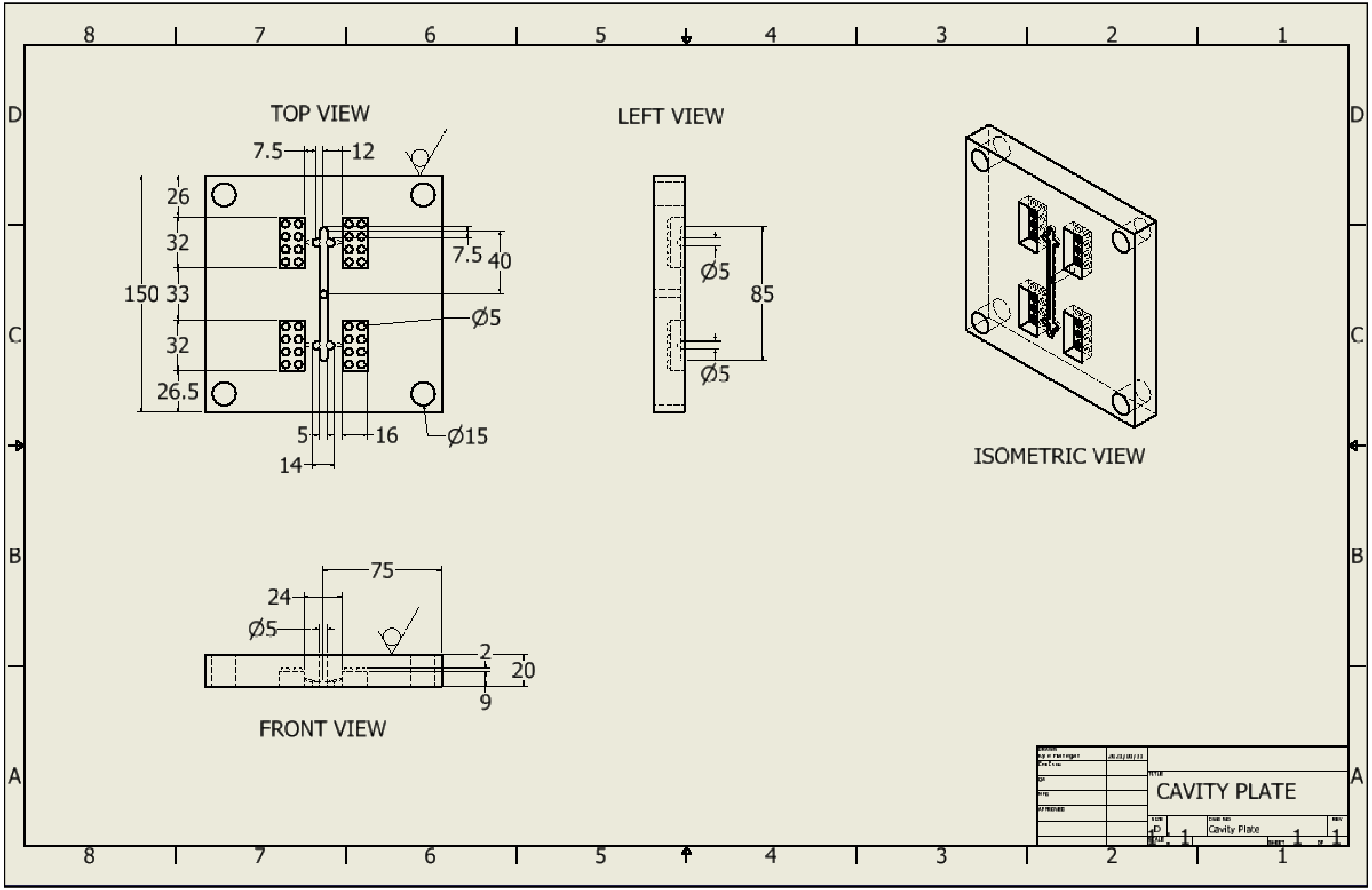
Assembly Drawing:



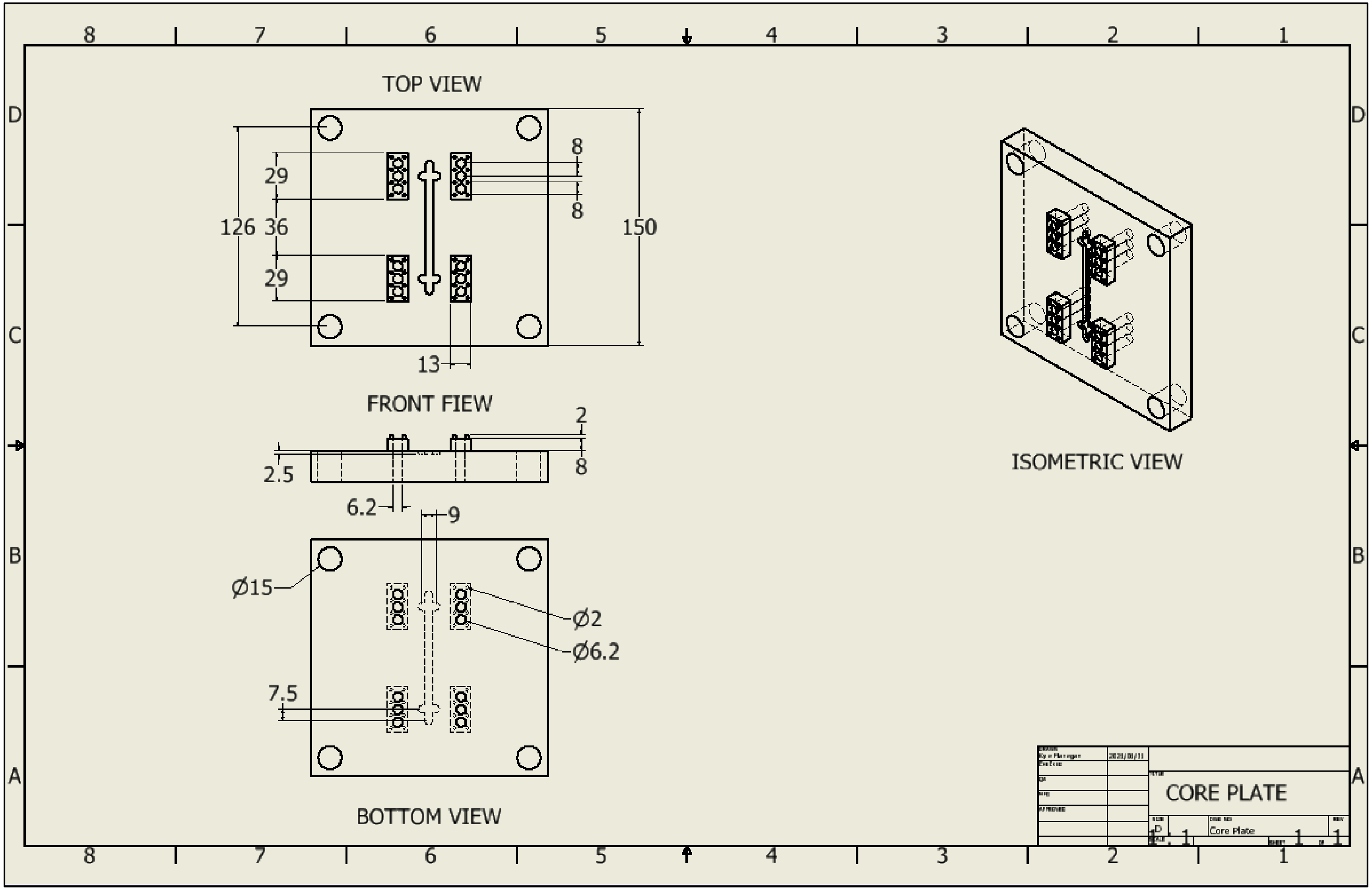
Top Plate:


TOP VIEW
Ø15
Ø30
150
75
12
12
150
75
20
FRONT VIEW
ISOMETRIC VIEW
TOP PLATE
Top Plate
8 7 6 5 4 3 2 1
D C B A

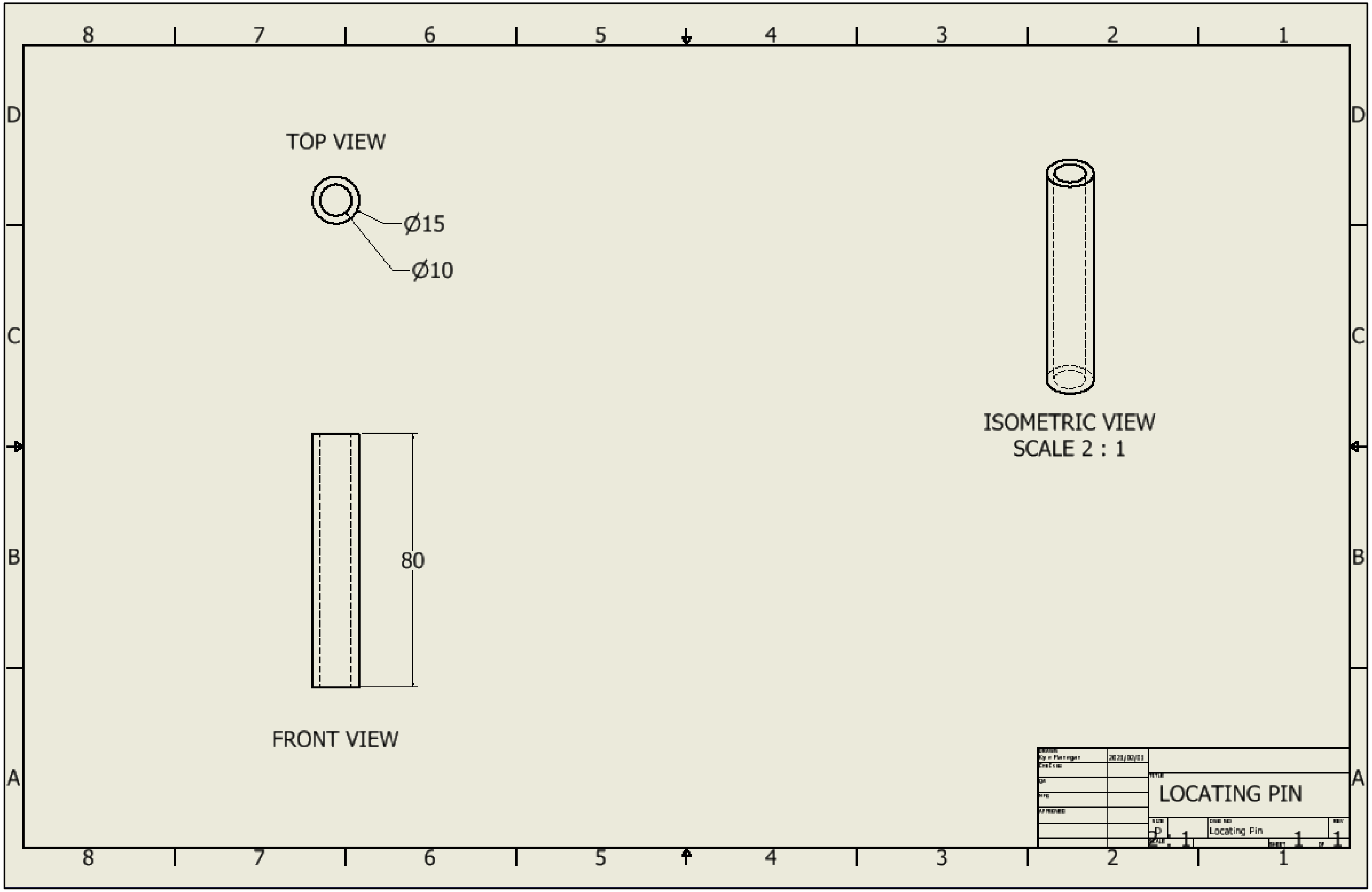
Cavity Plate



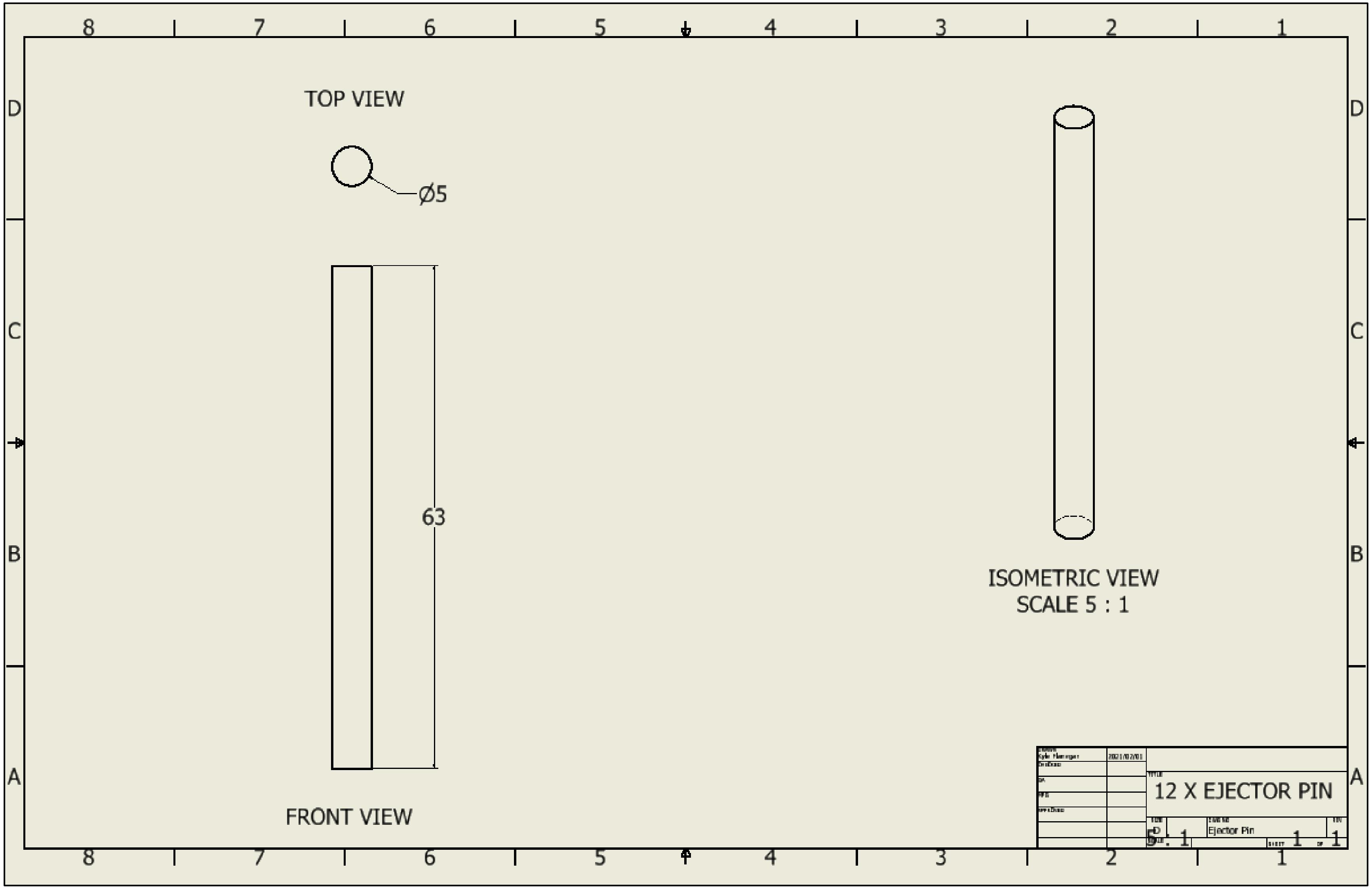
Core Plate


TOP VIEW
FRONT FIEW
BOTTOM VIEW
ISOMETRIC VIEW
126
36
29
29
8
8
150
13
2
2.5
8
6.2
9
Ø15
Ø2
Ø6.2
7.5
CORE PLATE
Core Plate

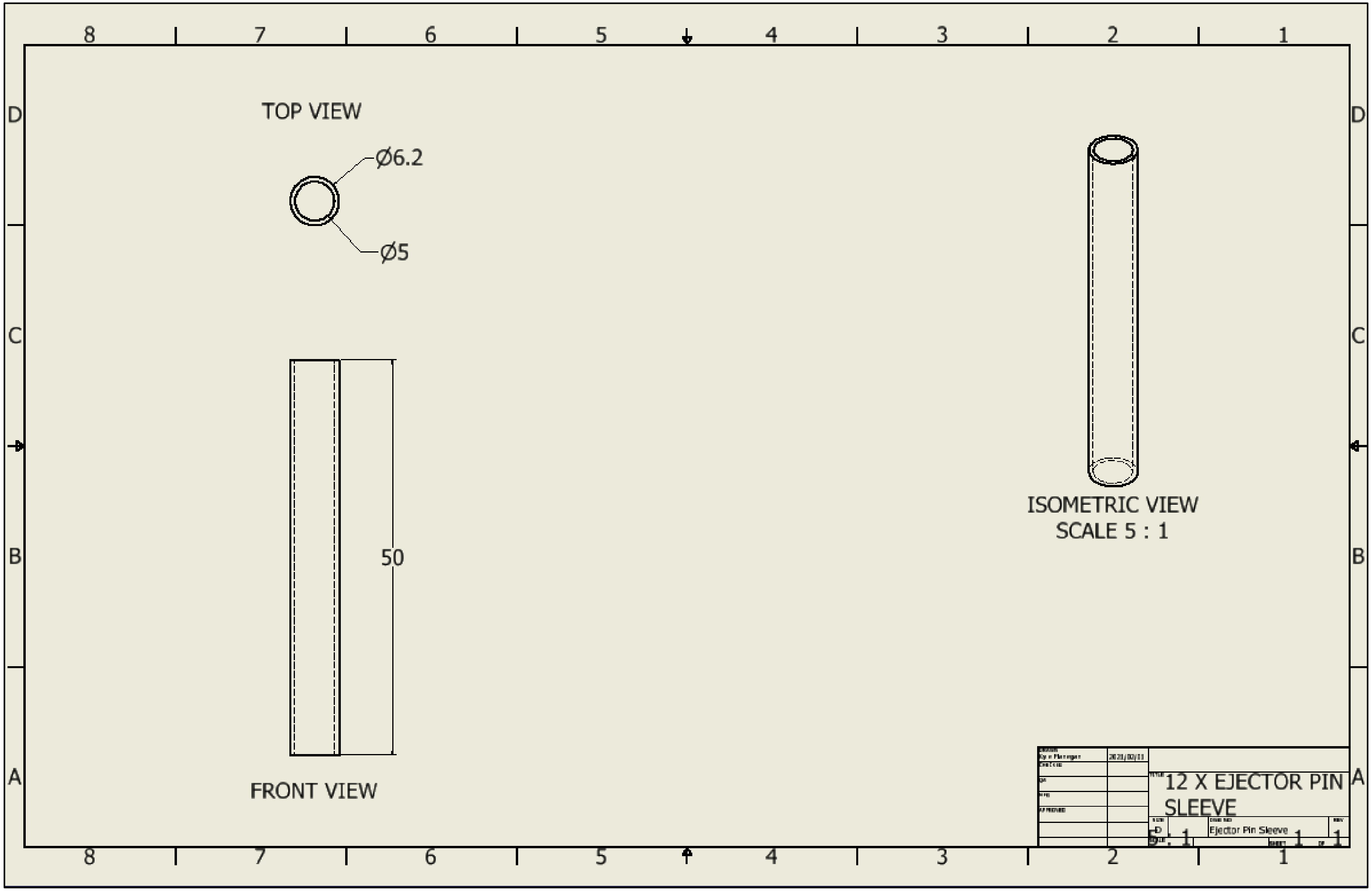
Locating Pin



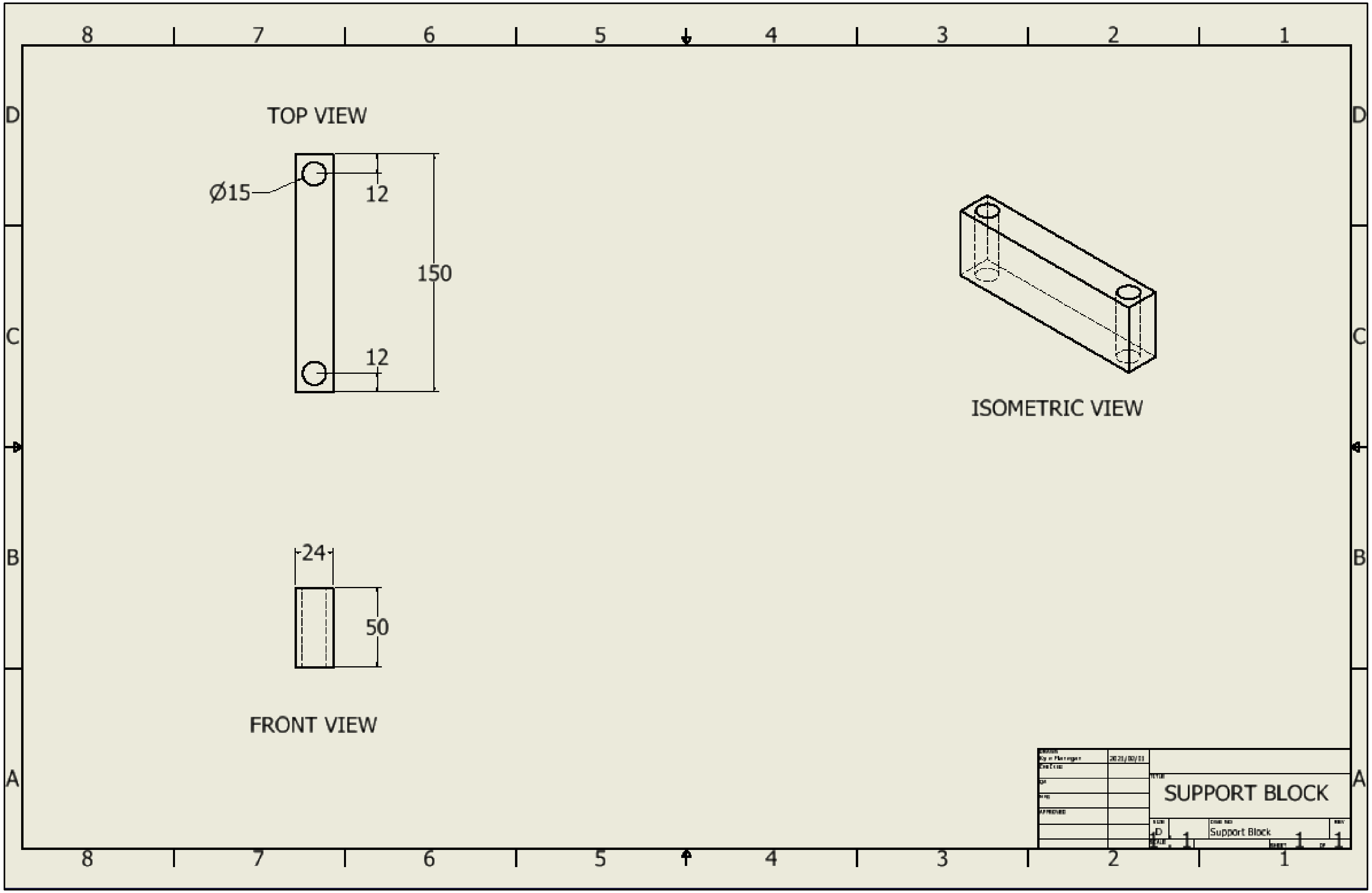
Ejector Pin


TOP VIEW
Ø5
63
FRONT VIEW
ISOMETRIC VIEW
SCALE 5 : 1
12 X EJECTOR PIN
Ejector Pin

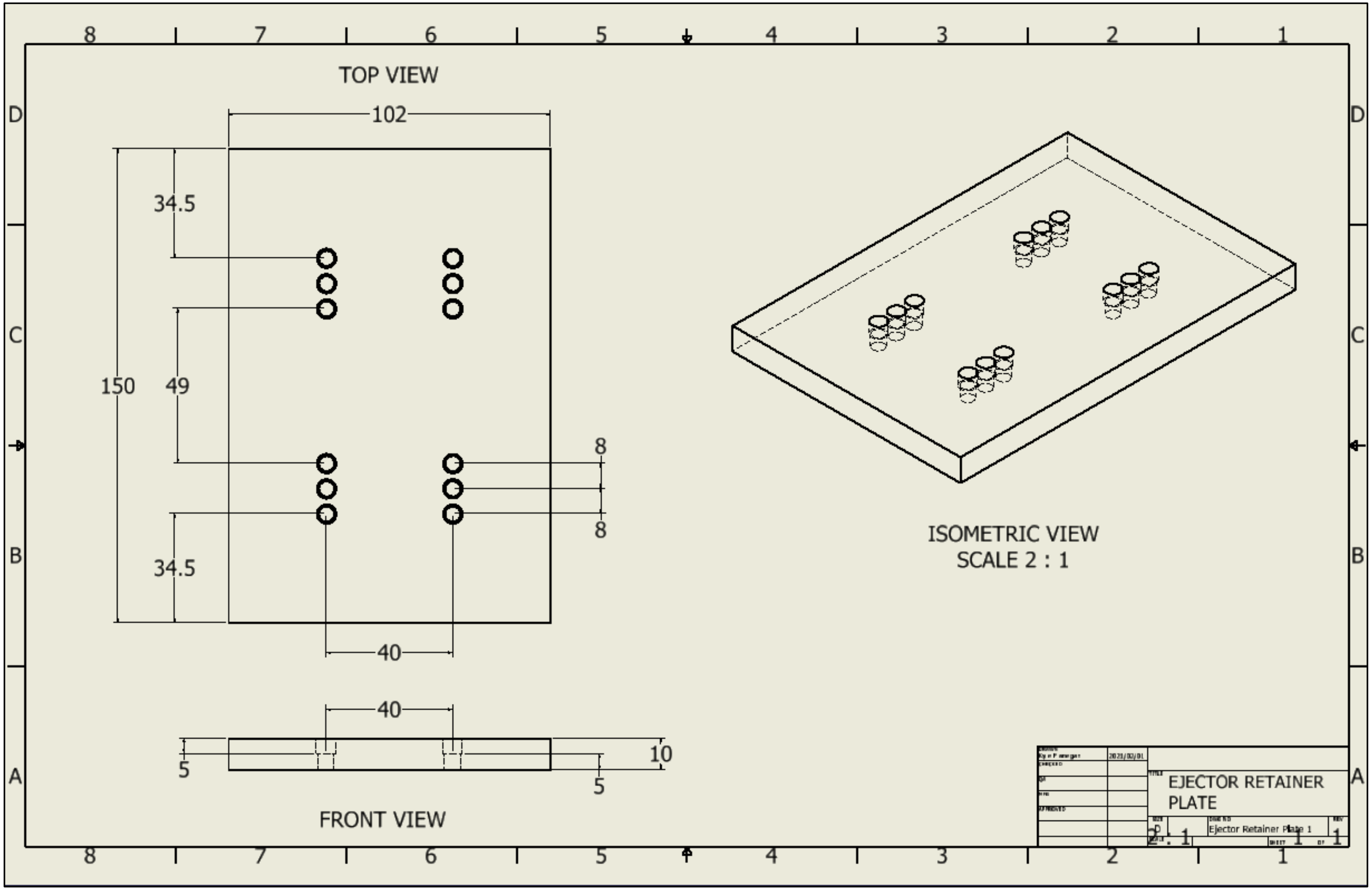
Ejector Pin Sleeve



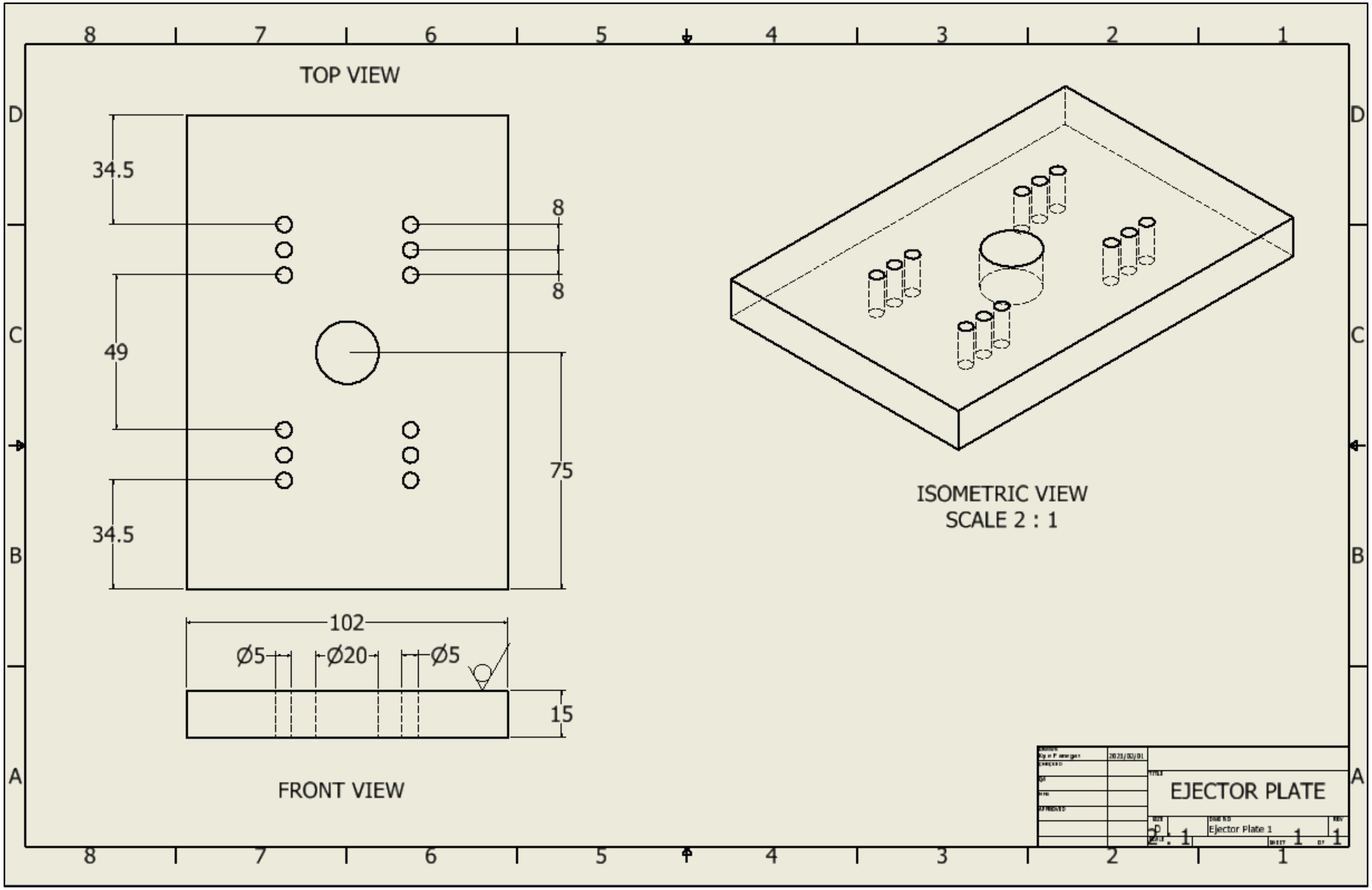
Support Block



Ejector Retainer Plate



Ejector Plate



Bottom Plate