

Modifying a Walk-Behind Two-stage Snow Blower for Use on a Concrete Driveway

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by

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TABLE OF CONTENTS

Cover page	1
Table of Contents	2
Abstract	3
Problem statement	4
Design Criteria	5
Customer profile	5
Customer requirements	5
Research, Existing Products, and Discussion	6
Existing Products	7
Budget, Schedule, Plan	7
Project timeline	8
Project Budget	9
Testing Procedures	10
Results and discussion	11
Works Cited	15
House of Quality	16
What went Wrong	18
Design Improvements	19
Design Constraints	20
Calculations	21
Brush Specifications	27
Parts Drawings	31
Assembly Drawings	62

ABSTRACT

The purpose of this design project was to modify a 2-stage snow blower so that it leaves a clean finish on a concrete driveway. The 2-stage snow blower I utilized for both my design, and testing purposes is a Yardman Snowbird, 24 inch 7 horsepower model made in the early 1980's shown below. My goal was to change as little as possible, in order to highlight the key improvements made. Those improvements are replacing the 4 straight-blade impeller with a 6 curved-blade impeller, replacing the runners on the side with lawnmower wheels, and attaching open wound coil brushes to the auger. To do this, I had to build an entire new front end of the snow blower. The only piece I could salvage off of the old one was the drive pulley attached to the impeller shaft. What this allowed me to do however, was to easily test the old and new design by simply changing them out. As for the testing itself, we received almost no snow this year, and I was unable to test in snow. Instead I utilized sawdust as my analogue. This is common practice in the industry, and then they verify the tests the following winter in snow.



PROBLEM STATEMENT

For me, and many others, snow blowers represent a unique challenge. They do not make contact with the ground and leave behind a thin film of snow. That film of snow becomes a sheet of ice overnight if it is not salted. This is not an issue on a blacktop driveway since the dark surface will heat up and melt the film away. A concrete driveway however, will reflect much of the light and will not melt the snow unless it is near freezing. Furthermore, a concrete driveway is very rough, which not only results in a thicker film left behind, it also prevents the snow blower skis from gliding across the surface. The final issue with a concrete driveway is they are poured in slabs approximately 10ft. x 10ft. at the largest. As the driveway ages, the ground settles and the slabs rise and fall accordingly. What was once a level driveway is now anything but. Snow Brushes offer a solution, but are severely limited to the amount of snow they can handle (approximately 1/3 brush diameter). That means even the largest machines, at 24 inches in diameter, can only handle 8 inches of powder.

That is my task, adapt a walk behind snow blower for use on concrete driveways, creating a hybrid with the power and capacity of a snow thrower, and the finish of a snow brush. My concrete driveway is the perfect candidate for testing as well, it is roughly 40 years old and 2400 square feet. I have shoveled it countless times and know what a good finish looks like and how to do it in the most efficient manner. So for a comparison during testing, it is ideal for side by side comparisons. What I will re-design is the following, the auger (the main intake blades of the snow thrower), auger housing (the main outside cover/scoop), chute (the part that directs the snow). Additionally I will need to re-design the auger drive mechanism. The snow thrower must roll and still be height adjustable with no bouncing over gaps in the driveway. It must also effectively throw the snow away from the driveway much more effectively so the impeller (the part that draws the snow in and actually does the throwing/blowing) must be addressed so that it not only throws the snow, but also draws it in more effectively. I will not touch any components of the engine, transmission, or clutch. I will be starting at the gear drive of the auger and working from there to re-design the auger housing to accommodate the changes and replace the runners with adequate wheels.

DESIGN CRITERIA

CUSTOMER PROFILE

The group of people I will target as customers, are adults that are homeowners, in the colder climates of the United States. Age is a little tricky to pin down because it is directly tied to homeownership, and that number is constantly changing. Currently, it is around 35 years old and up from there. I would not target commercial industries with the product I create, although small operations might benefit from my product. Later, if proven successful, I believe the concept could be applied to industrial equipment. In my neighborhood I have seen just as many women shoveling snow, and operating snow blowers as men, so I don't see a need to market to a specific gender. Skill level is the most important. Everything about my product must be designed for a novice to operate and maintain. The controls must be easy to use, and the maintenance must be as simple as possible. Any repairs necessary must not only be easily accessible, but able to be done in winter conditions. As I am designing this product I will have to keep the end customer of homeowners in mind. That also means I will have size and weight restrictions, along with using as many standard parts as possible. The geography for this product is a little complicated. Yes, there needs to be snow on the ground, but this can only handle so much. The Midwest is a prime target area, as we get enough snow to justify the purchase of a snow blower, but not so much snow as to need an industrial model. That means, for now, the western states and the New England states would be out of consideration, as they receive way too much snow for the capacity of my blower as it sits. As I mentioned earlier, this concept could be adapted at a later date to industrial models. Finally, I must meet the budget of a homeowner. That is a price range currently between 500 and 1000 dollars for a two stage snow blower. Beyond that price are the industrial levels which an average homeowner would not consider.

CUSTOMER REQUIREMENTS

Customer Features

- The primary customer feature is that my product is easy to use and maintain.
- Overall durability is also very important.
- Leave clean finish
- Affordable for homeowners

I have done a lot of research on this to find customer needs, along with what currently exists. For determining customer needs, I have utilized the internet, through discussion boards, videos/reviews, and general research. The additional customer features I have found to incorporate are as follows.

- Easy to replace shear pins
- Overall low maintenance and easily accessible parts
- Can be used in all snow conditions
- Easy to un-clog snow
- Maneuvers with little effort
- Does not scratch driveway

Product objectives to the above customer features respectively.

- Utilize “common” hardware sizes, and minimize tool usage.
- Appropriate types of materials used, strength, flexibility.
- Incorporate brushes into design.
- Target \$800 to \$1000 price range and a 15-30 year lifespan of use.
- Must be weatherproof.
- As many parts “tool-less” as possible.
- Impeller and auger must handle all amounts and types of snow.

There are many aftermarket products out there attempting to enhance a snow blower’s capability, along with DIY solutions other people have come up with. I plan on utilizing many of these ideas, none of which I claim as my own. These additional product objectives are as follows.

- Rubber paddles attached to the impeller will minimize if not eliminate clogging.
- Wheels, instead of skis on the scoop, along with an overall balance on the drive wheels.
- Synthetic scraper instead of metal, and brushes extending the auger’s reach.

Research, Existing Products and Discussion

The main product on the market for snow removal that leaves behind a clean finish, is the snow brush. These are powered sweepers that remove snow by sweeping it in front of them. Ariens makes arguably the best on the market for residential and commercial use. Then companies such as Koiak America, have made the products as big as possible for clearing airport runways (1). Snow brushes have an immense capability and are a proven concept to remove all types of snow and leave a clean finish behind. There are two limitations as mentioned above. The first is cost. An Ariens homeowner grade snow brush costs nearly \$2000. The second limitation is the capacity of a snow brush is limited to approximately 1/3 of the brush diameter. The Ariens homeowner snow brush is 18 inches in diameter, 28 inches wide, has an ideal depth of 6 inches of snow, and costs \$1969.00 (2). To spend that much money, and only be able to clear 6 inches of snow is a massive limitation. It is a limitation that a few companies have attempted to solve by making a machine with interchangeable components.

I have found many designs, and products for “combination” snow blower sweepers, that would come with interchangeable augers and brushes. Most notably is the one sold by Alibaba (3). It features an interchangeable auger, brush, and plow, all of which can be mounted to a single walk behind “tractor” unit. The idea is that for large amounts of snow, the operator would clear the snow with the auger or plow attachment, like a normal snow blower, and then switch to the brush to clear the film left behind. For small amounts of snow, only the brush is needed. This addresses the issue of owning two machines, but still leaves one area for improvement. The area in question is that you have to go over the surface twice to achieve the finish. That means taking twice the amount of time

to complete the job. This is where my design comes in, a hybrid between a snow blower and snow brush. To have one machine capable of handling large amounts of snow, and leaving a clean surface behind in one pass. The other benefit to a snow brush is they can handle miniscule amounts of snow, including powder and wet. A conventional snow blower cannot do this, but I intend on my design achieving this capability as well.

Existing Patents

I found one patent that is very close to my design, but it is on an industrial scale, and vehicle mounted, whereas mine is designed for residential use on a “walk behind” snow blower. The patent utilizes a giant brush to draw the snow in, where it is then sent through a series of fans, to an impeller and literally blown out the chute (4). My design uses this same concept, with two major exceptions. The first is that mine is on a residential scale and the patent is on a large industrial scale. The second difference is that my design utilizes an open wound coil brush attached to the auger instead of a cylinder brush. The last point on this patent is one that I find a little disappointing. They never built one, at least that I can find.

There are many products sold in stores that are combination machines as mentioned above. There are also many patents for all in one landscaping machines that can do everything from mowing the lawn to blowing snow. Since the products are sold in stores, and are not the same concept as my machine, I will not be referencing any patents concerning them.

Budget, Schedule, Plan

My budget for this project was initially \$1200.00. After major setbacks on all fronts however, the spending hit over \$3500.00. The timeline for this project is shown below. There is some lag-time in-between February 13, and March 13, and that is due to semester projects in other classes, along with midterm exams occurring before Spring Break of 2017, which begins on March 11, 2017 and lasts through March 19, 2017. During the weeks leading up to Spring Break, I put senior design on hold to complete the other necessary projects, and study for finals. From beginning until the end, I spent roughly 20 hours each week over 45 weeks on this project, totaling approximately 900 hours to get from a concept in my head, to a functioning prototype. Needless to say, my initial budget and plan were nowhere near reality.

PROJECT TIMELINE

1-Jun	Begin brush research
13-Jul	Begin contacting brush manufacturers
18-Jul	Begin to finalize manufacturer
29-Jul	Place order for brushes
30-Jul	Start creating solidworks models
10-Aug	Have entire "scoop" modeled
17-Aug	Cut out "scoop" pieces at Manufactory
19-Aug	Bend "scoop" pieces at Cincinnati Incorporated
27-Aug	Weld together bent pieces
3-Sep	Disassemble old snowblower to model entirely
4-Sep	Disassemble old snowblower to model entirely
5-Sep	Disassemble old snowblower to model entirely
6-Sep	Model entire old and new snow blower to get as many pieces cut out as possible before school is in full
11-Sep	cut out remaining 14 gage pieces
14-Sep	Order gearbox
15-Sep	Order necessary bearings from McMaster-Carr
18-Sep	cut out all 16 gage pieces to be bent or rolled
24-Sep	roll bend and weld all pieces
1-Oct	complete preliminary welding of two "halves"
2-Oct	Begin prep for joining two halves and design auger and impeller shaft
10-Oct	Senior design 2 starts Meet with Professor Cummings to determine schedule deadlines
13-Oct	Machine auger and impeller shafts
14-Oct	Weld together halves aligned by the shaft
15-Oct	re-assemble old snowblower
16-Oct	re-assemble old snowblower
21-Nov	Finish impeller assembly
25-Nov	Begin snowblower assembly
26-Dec	Disassemble snowblower to prep for paint
1-Jan	Prep scoop for paint
7-Jan	Prime scoop
9-Jan	build powdercoat rack/cart
14-Jan	Paint scoop
16-Jan	prep remaining parts for powdercoat
21-Jan	powdercoat parts
24-Jan	Final assembly
29-Jan	New snow blower completely built, ready for testing
2-Feb	groundhog sees shadow
13-Feb	Present to class
	Finish solidworks models and calculations
	Begin accruing sawdust for testing
	Fabricate new parts that don't fit
13-Mar	make chute
19-Mar	Begin testing
25-Mar	Complete testing
26-Mar	Disassemble, clean, and re-assemble snowblower, prepare for expo
6-Apr	Finish re-assembly, and prep for expo
7-Apr	MET expo
12-Apr	Faculty presentations
14-Apr	CEAS Showcase

PROJECT BUDGET

Part location	Name	Quantity	Cost	Total	Supplier
Bearing Side	Oil-Embedded Mounted Sleeve Bearing 7/8" shaft	2	23.48	46.96	McMaster Carr
Bearing Impeller	Ultra-Corrosion-Resistant Acetal Ball Bearing 1" shaft	1	50.8	50.8	McMaster Carr
Brushes	openwound coil brush #7 channel 20"OD 14"ID 10 inch long 1.25 rotations polypropylene	12	26.2	314.4	Carolina Brush
gearcase	Ariens gearcase 52101000	1	156.89	156.89	Jacks Small engine
plastic scraper	UHMW polyurethane .25" x 4" x 24"	2	12.08	24.16	McMaster Carr
Rubber paddles	60A Durometer rubber .25" x 2" s 36" cut to length as needed	1	18.01	18.01	McMaster Carr
steel wheels for powdercoat cart		6	5.97	35.82	
Steel					
scoop side,back, auger, impellers	4x8 14 gage cold rolled mild steel	2	101.44	202.88	American metal supply
auger, impeller shaft	1" x 4' steel round bar	1	20	20	Manufactory
impeller throat, housing, auger sprockets	4x5 16 gage cold rolled mild steel	1	68.9	68.9	American metal supply
Side cover, impeller blade	4x4 14 gage cold rolled mild steel	1	59.25	59.25	American metal supply
Auger sprocket collar	1" thick wall pipe 24" long	1	0	0	Grandpa's scrap pile
Impeller collar	2" round stock x 12" long	1	20	20	Manufactory
	4x8 14 gage cold rolled mild steel	1	130	130	American metal supply
	2x2 16 gage cold rolled steel	4	35	140	lowes
powdercoat cart	1.5" x 1.5" x 6' angle iron	12	14	168	
Hardware					
Miscellaneous bolts, nuts, washers	All required hardware	1	30	30	Tractor supply
Carbon fiber	50" x 1 yard of 2x2 twill 3k carbon fiber fabric	1	55.99	55.99	Rock west composites
Release ply	Fibre Glast Nylon release peel ply 60" x 1yd	1	14.45	14.45	Fibre Glast
Breather cloth	Fibre Glast 4oz 3yd roll	1	16.95	16.95	Fibre Glast
Sealant tape	Fibre Glast grey sealant tape	1	10.95	10.95	Fibre Glast
Bagging film	Fibre Glast strechlon 200 bagging film 60" x 3yd	1	13.95	13.95	Fibre Glast
Epoxy resin	Total boat epoxy resin 1 quart	1	49.99	49.99	Total Boat
Chute flange keeper	MTD 7310851A Chute Flange Keeper	3	2.02	6.06	Jacks Small engine
Time at manufactory (months)		12	100	1200	The Manufactory
Used snowblower		1	200	200	Grandpa's neighbor
Sawdust		6	5.79	34.74	Tractor supply
wire wheels		30	2.83	84.9	Lowes
Eastwood powdercoat		3	18.99	56.97	Eastwood
Paint		1	40	40	Sherwin williams
Primer		1	100	100	Sherwin williams
Mineral Spirits		1	25	25	Sherwin willams
Xylene		1	25	25	Sherwin willams
HVLP gun 1.4mm		1	40	40	amazon
HVLP gun 2.5mm		1	40	40	amazon
			Total cost	3501.02	excluding tax

Total spent: \$3501.02 excluding tax

TESTING PROCEDURES

Utilizing sawdust as the analogue for snow, I will compare the performance of the original two-stage snow blower I purchased, and a single-stage snow blower, against my new design. I will also measure the airflow, in Cubic Feet per Minute (CFM) entering the chute, with and without paddles mounted to the impeller to verify the design improvements.

- My two-stage snow blower test conditions
 - 12 inches of dry sawdust
 - 6 inches of dry sawdust
 - 6 inches of wet sawdust
 - 1.5 inches of dry sawdust
 - 1.5 inches of wet sawdust
 - 6 inches of dry sawdust with paddles removed
 - 6 inches of dry sawdust with brushes removed
- Original two-stage snow blower test conditions
 - 12 inches of dry sawdust
 - 6 inches of dry sawdust
 - 6 inches of wet sawdust
 - 1.5 inches of dry sawdust
 - 1.5 inches of wet sawdust
 - 6 inches of dry sawdust with paddles removed
- Single-stage snow blower test conditions
 - 6 inches of dry sawdust
 - 6 inches of wet sawdust
 - 1.5 inches of dry sawdust

1.5 inches of wet sawdust

Test	Sawdust Conditions	Sawdust Quantity			Airflow from Chute (ft. / min.)	Airflow from Chute (CFM)
		6 inches	12 inches	1.5 inches		
Shovel	Powder	1				
1-stage	Powder	15		16		
	Heavy	12		13		
Original 2-stage	Powder	8			1750	344
	Powder paddles	9	14	17	1654	325
	Heavy paddles	10		11		
My 2-stage	Heavy	3		4		
	Powder	2	5	6	2006	198
	No paddles	7			2067	204
	No brushes	18				
Terms						
Powder	Dry sawdust wetted down with 4 gallons of water per 20 cubic feet					
Heavy	Dry sawdust wetted down with 12 gallons of water per 20 cubic feet					
Paddles	Rubber strips mounted to half of the impeller blades, alternating.					
Chute	Chute Diameter (in.)	ft	Area (ft^2)			
Original	6	0.5	0.196			
My 2-stage	4.25	0.354	0.099			

RESULTS AND DISCUSSION

The results from testing could not have made me happier. As you can see in the table above, I tested a wide array of “snow” conditions. Under each load, my snow blower produced the same, clean finish every time. The finish left on the driveway was superior, not only to the original 2-stage snow blower, but also to shoveling. The single-stage did leave a cleaner finish than my 2-stage, but it bogged down quickly, as expected in heavy, deep “snow” conditions. As you can see in the table above, I alternated between “snow” conditions constantly. This was done in an attempt to maintain the desired moisture levels necessary for each test over the two day testing period.



The pictures above illustrate each snow blower operating under the six inches of heavy sawdust. The original 2-stage is the top left image, the single-stage is the top right image, and my 2-stage is on the bottom. As you can see the six blade impeller is throwing the sawdust further than the four blade impeller on the original. All images are taken at the start of the first pass, just as the snow blower has completely entered the test patch. The reason I am on the left side running my 2-stage versus the right side for the others, is to attempt to accommodate for shifting wind conditions. I wanted to re-use as much sawdust as possible in order to minimize my cost. As you can see however, the wind shifted back to blowing right-to-left.



My Two-stage 1.5" Dry Sawdust



My Two-stage 1.5" Wet Sawdust



My Two-stage 6" Dry Sawdust



My Two-stage 6" Wet Sawdust



My Two-stage 12" Dry Sawdust



Shoveled 6" Dry Sawdust



Original 1.5" Dry Sawdust



Original 1.5" Wet Sawdust



Original 6" Dry Sawdust



Original 6" Wet Sawdust



Original 12" Dry Sawdust



Single stage 1.5" Dry Sawdust



Single stage 6" Dry Sawdust



Single stage 6" Dry Sawdust



Single stage 1.5" Wet Sawdust

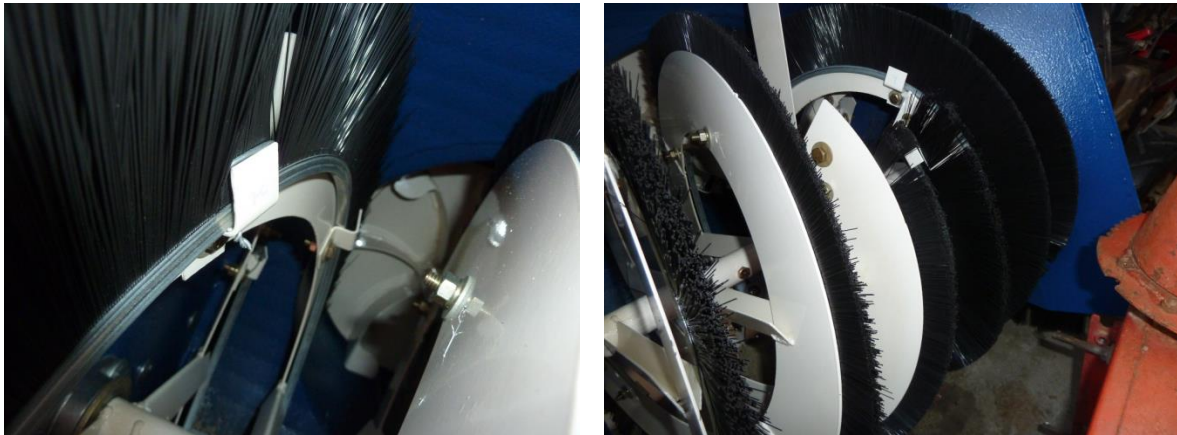


As you can see from the results above, each “snow” condition produced about the same result for each machine. The final image above is of my 2-stage snow blower in 6 inches of powder with the brushes attached, as they were for all of the previous tests (left), and with the brushes removed (right). It is clearly shown that the pass on the left, is much cleaner than the pass on the right. This illustrates the direct effect brushes have on the finish left behind by the snow blower. The method for attaching the brushes is shown on the next page.

The single-stage snow blower, as expected, managed 1.5 inches of sawdust very well, and left a clean finish. However, it could not handle 6 inches of wet or dry sawdust and bogged down quickly.

The original two-stage snow blower with its straight four-blade impeller handled all sawdust conditions presented, exceptionally well.

My two-stage snow blower, with its curved six-blade impeller, and coil brushes, demonstrated sufficiently that the modifications met the project objectives in all snow conditions. The wheels had slightly more problems than skis in deep snow, but overall performed well thanks to the new drift cutters and brush guards. The new impeller performed admirably against the original, and all modifications have demonstrated a proof of concept. The brushes left behind a cleaner finish than shoveling. I believe they were justified in preliminary sawdust testing to move forward to actual snow tests. The only major problem was the snow blower moved too quickly in first gear, and was very difficult to handle. As mentioned before, using a modern machine would resolve this issue.



As you can see in the images above, the brushes are attached in front of the auger, by wires attached to tabs which are bolted to the auger. The auger is pushing the brush, which maximizes the force the brush can exert, and minimizes any gaps that would allow snow to build up. The reason the brushes only protrude an inch from the auger, while 2 inches is supported, is to give the bristles room to move and sweep in the direction of travel, without yielding. Attaching them directly to the end of the auger would eliminate any support they receive from the auger, and shortening the bristles would make them prone to yielding during operation. Short, rigid bristles would also wear faster, and would behave less like a broom, and more like a scraper, completely defeating the purpose of having them.

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Interaction Matrix															
	Engineering Requirements	Utilize common hardware	Strength, toughness	Brush density, strength	Minimise new parts	Number of steps	Simple components	Snow capacity, torque, rpm	Impeller clearance	Push force, weight	Scraper hardness	0	0	0	0
Engineering Requirements		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Utilize common hardware	1				1										
Strength, toughness	2			1							1				
Brush density, strength	3							3							
Minimise new parts	4						3								
Number of steps	5						1								
Simple components	6														
Snow capacity, torque, rpm	7														
Impeller clearance	8														
Push force, weight	9														
Scraper hardness	10														
	0 11														
	0 12														
	0 13														
	0 14														

WHAT WENT WRONG

- Converting scoop to dxf changed dimensions, resulting in the back being roughly 2 inches short
 - Burnt up 2 1/4" drill bits drilling impeller shaft connection... Grandpa drilled it in 5 minutes
 - Burnt up 1 5/16" drill bit and melted another drilling impeller shaft and collar... Supervisor from co-op drilled it in 5 minutes
 - Paint would not cure, requiring heat, which meant another 50 dollars in heat lamps and bulbs
 - Powder coat gun went PUFFFFF, and half a can of powder was on the floor
 - Powder coat oven would not maintain temperature.... For only me
 - Welded mounting brackets too low requiring new holed to be drilled in main housing
 - Did not take into account side forces for wheel brackets, and bent them
-
- Plasma table acted up, resulting in me having to purchase more steel
 - I did not realize the scoop back was shorter than intended until I was welding the back on and realized it was crooked. And purchasing more steel
 - My parts required a rolling cart for the powder coat oven, therefore I had to make a powder coat cart, the wheels alone were 40 dollars, total cost of 200 dollars (still cheaper than buying one), also broke another 5/16" bit
 - Broke the vertical mill, broke the lathe (Luckily only minor problems)
 - Burnt up my corded drill, which cost 30 dollars to replace
 - Had to research and purchase completely new gear case because mine is no longer made.
 - Acquired face shields, respirators, universal socket joints, cobalt drill bit set, new pair of welding gloves, sandblasting gun, 2 spray paint guns, anemometer, woodruff key cutter
 - Greatly underestimated amount of powder coat required, resulting in 60 dollars being spent, 30 of which was shipping, 3 separate times
 - Gear case randomly started leaking, resulting in the purchase of more oil
 - Warpage from welding, and lost time due to drill bits and machines breaking set me back over 2 months
 - Forgot to re-assemble old snow blower, resulting in 2 hours lost to testing, also did not have testing supplies ready/organized, and lost another 3 hours, so what was supposed to be 6 hours of testing, was barely 2
 - During first test run with the brushes attached, they were flipped completely inside out from clockwise wound, to counter-clockwise. It took all my strength to get them back the correct way, and luckily, nothing broke.
 - T-handle bolt kit I purchased used carriage bolts that were not standard size (3/8 square on 5/16 bolt) and were too short, having already cut the square holes I had to re-make the wheel brackets for 3/8 carriage bolts, and purchase four new 3/8" t-handles costing me 30 dollars total.
 - Oh... and it did NOT snow
-
- In total
 - I have bought enough steel to build this twice
 - I have broken 60 dollars in drill bits
 - Spent 100 dollars on wire wheels to re-clean metal that for endless reasons, was outside too long and rusted

- Spent 50 dollars on grinding wheels to cut off and fix the crooked scoop back
- Everything I could have saved money on, I already had purchased, or needed NOW
- I intended to spend roughly 1,500 dollars, I have spent over 3,000, including Manufactory time, and if nothing had gone wrong, would have cost roughly 600 dollars plus 300 dollars at the manufactory over the summer.
- The total cost of my upgrade, is roughly 150 dollars

DESIGN IMPROVEMENTS

There were many improvements I could have made to this design which would have allowed assembly to flow more easily. Most of these changes are a result of a design failure.

- Incorporating the slots for the wheel bracket support with the “scoop side” flat pattern. This would eliminate the need for the “wheel support” part, along with the four bolts holding each part to the scoop side.
- Changing the swept back sides on the “scoop back” to forward sweeping. This would eliminate the points which protrude three inches from each side, and replace them with a smooth rounded edge. I cannot count the number of times I picked the piece up, and nearly gouged my eye out because of this design. So this is very much a safety concern, as I was very lucky.
- Utilizing a modern snow blower, and modern stamping procedures. Modern snow blowers utilize augers that are between 11 and 16 inches in diameter, depending on the model, and manufacturer. My snow blower utilizes an auger that is 18 inches in diameter. This would allow the design to be much more compact, as my machine fully assembled, is just over six feet long. The auger on a modern snow blower also rotates at nearly twice the revolutions per minute, compared to mine. Accounting for the smaller auger, this translates to a minimum 10 percent increase in linear velocity of the auger. The higher rpm would improve the sweeping ability of my machine. Modern machines utilize much lighter gage steel, and stamp gussets into them for strength. I did not have the capability to do that, so I was limited to 14 and 16 gage steel. The front end of my snow blower alone weighs over 100 pounds. By utilizing thinner materials, such as 20, and 24 gage steel, the weight can be cut in half. Finally, a newer machine would move slower due to the fact that the transmission does not have 30 years of wear on it, and that would allow for a much cleaner finish as well.
- I would stamp out the auger flights instead of bending it by hand. That would give me a perfect helix, instead of the “v” shape I have. Again, I did not have the capability to stamp out the auger, so bending them by hand was my only option.
- I would incorporate a tab on the scoop side, to allow for the removal of the “scoop side cover” on each side of the machine. This would allow for easy access to the “auger shaft” bolts, and to the wheels if necessary.
- I would stamp out the impeller in order to minimize welding
- It is not necessary to use an “impeller collar” two inches in diameter, and I would reduce this to 1.5 inches to allow for easier welding, and weight reduction.

- I would use either molded plastic, or stamped steel, for the chute instead of carbon fiber. I had no other way of obtaining a seamless chute, and carbon fiber was a material I have always wanted to work with.
- I would powder coat the entire scoop, instead of painting it. Powder coat is much easier to apply in tight spaces than paint. I could not powder coat anything that large however at the facilities I had access to.
- I would utilize stainless steel for all of the hardware, brush channels, and brush brackets. The reason for this is to minimize corrosion. A snow blower can have a life of 10 to 30 years, and is exposed to very harsh operating conditions. It is inevitable that parts will need replaced, and removing them easily is crucial.
- I would also engineer optimum brush specifications that would give me the cleanest results, and have an optimum life.

Design Constraints

Over the course of this project there were many design constraints that were based not on engineering, but on physical properties I had no control over.

- Minimize brush contact to reduce wear
- Hand sheet metal brakes are limited to 16 gage steel
- No ability to add gussets to thinner sheet metal, so 16 gage is the minimum thickness
- Must maintain access through auger to bolts, gearbox, and shear pins.
- Polypropylene is the only bristle material with adequate bend recovery when wet that is resistant to chemicals and mold.
- I only have access to standard pulleys and gearboxes, so my ratios and rpm cannot change for the impeller or auger.
- All bearings must be permanently lubricated because they cannot be accessed once the machine is fully assembled. Also, they must be able to operate under cold winter temperatures.
- Finally, I do not have unlimited funds, so cost is certainly a major constraint.

These constraints led me to choices that from an engineering point of view, were not ideal. I would have preferred to reduce the weight as much as possible, and utilize thicker materials when necessary. There were better materials than polypropylene, but they were not common, or cost effective. The materials also were not as resistant to chemicals and mold as polypropylene. I was also limited by my ability to fabricate parts, which meant I was using thicker sheet metal than necessary to match my ability.

CALCULATIONS

Bearing verification

I needed 3 bearings for this build, two smooth bearings for the auger shaft, and a roller bearing for the impeller shaft. The smooth bearing specifications exceeded my needs considerably since they are essentially a solid metal bracket. I had trouble though, finding a roller bearing that did not need lubricated, that could withstand the forces necessary, and did not cost an absurd amount of money.

With cost as the primary factor, I settled on acetal bearings supplied by McMaster-Carr. They are rated to a dynamic load of 92 pounds, and a maximum speed of 729 rpm, and have a temperature range between -40°F and 180°F.

I was able to measure my impeller rpm by timing how long it took the auger to rotate a number of revolutions, then multiplying that number by 10 to account for the 10 to 1 reduction in speed from the worm drive gearbox.

I came up with approximately 730rpm for the impeller speed. The part I did not know, was how much weight the bearing could support, and that is what I calculated.

All equations and tables are referenced from “Machine Elements in Mechanical Design” fifth edition by Robert L. Mott Chapter 14 “Rolling Contact Bearings”

$$L_d = (h)(rpm) \left(\frac{60min}{hr} \right)$$

I assumed 30,000 hours based on table 14-4 (electric motors, industrial blowers, general industrial machines, conveyors)

$$L_d = (30,000hr)(729) \left(\frac{60min}{hr} \right)$$

$$L_d = 1,312,200,000 \text{ revolutions}$$

$k = 3.00$ for ball bearings

$$C = P_d \left(\frac{L_d}{10^6} \right)^{1/k}$$

$$C = 92lb \left(\frac{1,312,200,000}{10^6} \right)^{1/3}$$

$$C = 1007.2lb$$

Now that I have my dynamic load rating, I want to see what happens if for some reason my rpm measurement is higher than I thought. I used twice the measured rpm.

$$L_d = (h)(rpm) \left(\frac{60min}{hr} \right)$$

$$L_d = (30,000hr)(1458) \left(\frac{60min}{hr} \right)$$

$$L_d = 2,624,400,000 \text{ revolutions}$$

$$C = P_d \left(\frac{L_d}{10^6} \right)^{1/k}$$

$$1007.2lb = P_d \left(\frac{2,624,400,000}{10^6} \right)^{1/3}$$

$$P_d = 73.02lb$$

So even at twice the rpm, I can hang 73.02 pounds off of the bearing and it will still operate. My impeller weighs just under 10 pounds, so that leaves about 63 pounds of resistance. That is far less than anything ice or snow can do, so I know my bearing is safe.

Brush Deflection

The key component in this entire project is the open wound col brushes mounted to the auger. The key detail I need is the amount of ground contact I can have before the brush yields. If the bristles yield, they won't sweep the ground as well, if at all, so knowing the amount of ground contact is crucial. The problem I had throughout this was I knew almost nothing in terms of brush specifications. To solve this I needed the brushes themselves, so that I had a starting point. To obtain the brushes I made some assumptions about the bristles based upon measurements of shop floor brooms, and conventional brushes used to scrape snow off vehicles. All of them had bristles three inches long, and between 0.014 and 0.020 inches in diameter depending on brush width. Thinner brushes used larger diameter bristles, while thicker shop floor brooms used smaller diameter bristles. So I chose 0.020 inches in diameter and three inches long based on the information I collected. Now the only variable left is to calculate the bristle deflection before they yield.

According to the table Carolina Brush's website, the tensile modulus(E) of polypropylene is 740ksi, and the tensile strength is 53ksi. For these calculations I will utilize the equations and tables found in "Applied Strength of Materials" fifth edition, by Robert L. Mott. I will be assuming perfect deformation and uniform stresses throughout each bristle. I also measured the number of bristles in one inch of the brush. That number is approximately 800 bristles.

Moment of inertia in a single bristle

$$I = \frac{\pi D^4}{64}$$

$$I = \frac{\pi(0.020in)^4}{64}$$

$$I = 0.000000008$$

The two types of deflection I measured are in the direction of rotation, where only the force of the bristle is accounted for, and in the direction the auger is pushing, where the forces take into account the deflection caused by the auger.

Yield of a single bristle 3 inches long, and 0.020inches in diameter anchored on one end, with the force exerted on the other vertically as shown in table A-24a. I obtained the necessary measurements for y_b by deflecting the bristle until it was 0.25in off the ground, and measuring that distance.

$$y_b = \frac{-PL^3}{3EI}$$

$$1in. = \frac{-P(3in.)^3}{3(740,000psi)(0.000000008)}$$

$$P = -0.0006458lb$$

Note: negative signifies downward direction

Total force exerted by bristles

$$P_{total} = -0.0006458lb * 800 \text{ bristles}$$

$$P_{total} = .517lb \text{ per inch of bristles}$$

Stress in one bristle

$$\sigma = \frac{Mc}{I}$$

Moment in one bristle

$$M = PL$$

$$M = 0.0006458lb * 3in$$

$$M = 0.0019374in*lb$$

$$c = \frac{D}{2}$$

$$c = \frac{0.020in.}{2}$$

$$c = 0.010in$$

$$\sigma = \frac{(0.0019374in * lb)(0.010in)}{0.000000008}$$

$$\sigma = 2421.75psi = 2.4ksi$$

This is well below the tensile strength of 53ksi, so there is no risk of yield.

Next I need to verify that it will not yield with the auger supporting the bristles. All assumptions mentioned above remain and the diagram utilized is A-25d.

$$y_c = \frac{-PL^3}{EI} \left(\frac{a^2}{4L^2} + \frac{a^3}{3L^3} \right)$$

$$0.75in = \frac{-P(2in.)^3}{(740000psi)(0.000000008)} \left(\frac{(1in.)^2}{4(2in)^2} + \frac{(1in.)^3}{3(2in.)^3} \right)$$

$$P = -0.005328lb$$

Note: negative signifies downward direction

Total force exerted by bristles

$$P_{total} = -0.005328lb * 800 \text{ bristles}$$

$$P_{total} = 4.262lb \text{ per inch of bristles}$$

Stress in one bristle

$$\sigma = \frac{Mc}{I}$$

Moment in one bristle

$$M_B = -Pa$$

$$M_B = 0.005328lb * 1in$$

$$M_B = 0.005328in * lb$$

$$c = \frac{D}{2}$$

$$c = \frac{0.020in.}{2}$$

$$c = 0.010in$$

$$\sigma = \frac{(0.005328in * lb)(0.010in)}{0.000000008}$$

$$\sigma = 6660psi = 6.66ksi$$

This is also well below the tensile strength of 53ksi, so there is no risk of yield.

Shear pin Calculation

The final calculation is the most important piece of this entire system. The shear pins prevent the snow blower from destroying itself, or seizing the engine. The goal is to have them strong enough so the snow blower can function in deep snow, but weak enough that if the auger were to get jammed, they would break and prevent any damage.

The first step is to determine the torque in the auger shaft. I expect the value to be well above any forces required to break the pins, to that there is no damage to the engine. I also want the shaft to be many times stronger so that it suffers no damage when the pins break. For these calculations I am assuming double shear on one pin with half of the shaft torque.

First I need to calculate the torque output from the engine based on the auger rpm and gearbox and pulley ratios. The engine is rotating at 3650rpm, as determined by the gear and pulley reductions, and outputting 7hp as advertised by the model number. The worm drive has a 10 to 1 reduction.

All equations and tables are referenced from “Machine Elements in Mechanical Design” fifth edition by Robert L. Mott

$$T = \frac{63,000 (P)}{n}$$
$$T = \frac{63,000 (7hp)}{3650rpm}$$
$$T = 120.882in * lb = 10.068ft.* lb$$

This torque specification is comparable to other engines of similar size, so it is valid.

$$T_{shaft} = \left(\frac{D_{impeller pulley}}{D_{motor pulley}} \right) * (worm drive ratio) * T$$
$$T_{shaft} = \frac{8.75in.}{1.75in.} * (10) * (120.882in.* lb)$$
$$T_{shaft} = 6041in * lb$$

This is far greater torque than anything the auger will contact, and will easily overcome the 5/16 inch diameter shear pins.

The area of one shear pin in double shear is $0.1534in.^2$ and half of the torque in the auger shaft is $3020.5in*lb$. The force (V) applied to the end of the 18 inch diameter auger is therefore 335.61 pounds of force. Again, that is far higher than anything the auger will come into contact with, and should have no issues overcoming the shear pins.

$$S = \frac{4V}{3A}$$
$$S = \frac{4(335.61lb)}{3(0.1534in.^2)}$$
$$S = 2917.09psi = 2.917ksi$$

Ideally the pins will be 5 to 10 times below that shear strength.

Next, I need to verify the shaft will not be damaged by that maximum shear strength. The shaft is 1 inch in diameter and is analyzed where the 5/16 hole goes through it.

$$J_{shaft} = \frac{\pi D^4}{32}$$

$$J_{shaft} = \frac{\pi(1in.)^4}{32}$$

$$J_{shaft} = 0.09817$$

$$J_{pin} = b * h^3 \left[\frac{1}{3} - (.21) \left(\frac{h}{b} \right) \left(\frac{\left(1 - \left(\frac{h}{b} \right)^4 \right)}{12} \right) \right]$$

$$J_{pin} = (1in.) * (0.3125in.)^3 \left[\frac{1}{3} - (.21) \left(\frac{0.3125in.}{1in.} \right) \left(\frac{\left(1 - \left(\frac{0.3125in.}{1in.} \right)^4 \right)}{12} \right) \right]$$

$$J_{pin} = 0.01001$$

$$\tau_{max} = \frac{Tc}{J_{shaft} - J_{pin}}$$

$$\tau_{max} = \frac{(3020.5in * lb)(0.5in)}{(0.09817 - 0.01001)}$$

$$\tau_{max} = 17130.78psi = 17.13ksi$$

As expected, the shaft is still many times stronger than the pin, even at the weakest point, so there is no risk of damage.

Ideally, the shear pins would have approximately one-fifth the yield strength specified. That equates to 1.4585ksi for the entire pin, or 0.72925ksi for a single side of the pin. As long as the material has that yield strength or lower, the design requirements will be met. The other option is to reduce the area of the pin at the point of contact with the shaft down from 5/16 inches to the desired amount to meet the yield strength requirements.

BRUSH SPECIFICATIONS

Open wound coil brush order receipt sheet as per Carolina Brush.

ORDER NO. 6571400
 CUSTOMER NO. 1328400

BILL TO:
 BRETT RANKEY
 [REDACTED]

SHIP TO: 888
 BRETT RANKEY
 [REDACTED]

Date	Customer Order No.	Date Entered	Shipped By	Terms
	VERBAL-BRETT	8/01/16	UPS-GROUND	VISA CARD

Qty Ord	Qty Shp	B O	Item #	Description	Price	Uom	Tax Code	Amount
6			53605	COIL BRUSH, #7, 20" OD, 10" LONG WHEN STRETCHED, RH, .020 BK POLY	26.200	EA	NO	157.20
6			53606	COIL BRUSH, #7, 20"OD, 10"LONG WHEN STRETCHED, LH, .020 BK POLY	26.200	EA	NO	157.20

Open wound coil brush quote as per Carolina Brush showing both the stainless steel channel, and the galvanized steel channel. I used the galvanized steel on this project to save on cost.



CAROLINA BRUSH

3093 Northwest Blvd. P.O. Box 2469 Gastonia, N.C. 28053-2469
 phone 704-867-0286 Fax 704-861-0772 toll free 800-822-1160
 webpage www.carolinabrush.com email info@carolinabrush.com

DATE 7-26-16

TO: BETT BANKKY



Quotation

28139

FAX: ** REVISED ** 7/28/16

PART NUMBER	DESCRIPTION	QUANTITY	UNIT	PRICE
ITEM 1	Per Doug Whitworth, we are quoting as follows: COIL BRUSH BAND: #7 ELECTRO-GALVANIZED FILL: .020 BLACK LEVEL POLYPRO O.D. OF COIL: 20" WHEN STRETCHED TO 8" PITCH I.D. OF COIL: 14" WHEN STRETCHED TO 8" PITCH COIL LENGTH: 10" WHEN STRETCHED TO 8" PITCH CLOSE WOUND NUMBER OF TURNS: 1.25 DIRECTION WOUND: RIGHT HAND	6	EA	26.20
ITEM 2	COIL BRUSH SIMILAR TO ITEM 1 EXCEPT DIRECTION WOUND DIRECTION WOUND: LEFT HAND	6	EA	26.20
ITEM 3	COIL BRUSH BAND SIZE & TYPE: #7 STAINLESS STEEL FILL: .020 BLACK LEVEL POLYPRO O.D. OF COIL: 20"	6	EA	34.24
*** Continued ***				

Quotation for acceptance within 30 days
 Terms: NET 30-PENDING APPROVAL
 F.O.B. GASTONIA, NC
 Delivery: 4-5 WEEKS

CAROLINA BRUSH COMPANY

Fred P. Spach, Jr.
 President



CAROLINA BRUSH

3093 Northwest Blvd. P.O. Box 2469 Gastonia, N.C. 28053-2469
phone 704-867-0286 Fax 704-861-0772 toll free 800-822-1160
webpage www.carolinabrush.com email info@carolinabrush.com

DATE 7-26-16

TO: BRETT RANNEY



Quotation

28139

FAX:

** REVISED ** 7/28/16

Page 2

PART NUMBER	DESCRIPTION	QUANTITY	UNIT	PRICE
ITEM 3	WHEN STRETCHED TO 8" PITCH I.D. OF COIL: 14" WHEN STRETCHED TO 8" PITCH COIL LENGTH: 10" WHEN STRETCHED TO 8" PITCH CLOSE WOUND NUMBER OF TURNS: 1.25 DIRECTION WOUND: RIGHT HAND			
ITEM 4	COIL BRUSH SIMILAR TO ITEM 3 EXCEPT DIRECTION WOUND DIRECTION WOUND: LEFT HAND These brushes are manufactured to your specifications and are not returnable except for defects in workmanship or materials. FOR ORDERS OR INQUIRIES CALL 800-822-1160 ASK FOR CUSTOMER SERVICE	6	EA	34.24

Quotation for acceptance within 90 days
Terms: NET 30-PENDING APPROVAL
F.O.B. GASTONIA, NC
Delivery: 4-5 WEEKS

CAROLINA BRUSH COMPANY

Fred P. Spach, Jr
President

Strip brush quote for wheel bracket guard as per Carolina Brush.



CAROLINA BRUSH

3093 Northwest Blvd. P.O. Box 2469 Gastonia, N.C. 28053-2469
 phone 704-867-0286 Fax 704-861-0772 toll free 800-822-1160
 webpage www.carolinabrush.com email info@carolinabrush.com

DATE 9-12-16

TO: BETTE BANKEY



Quotation

28375

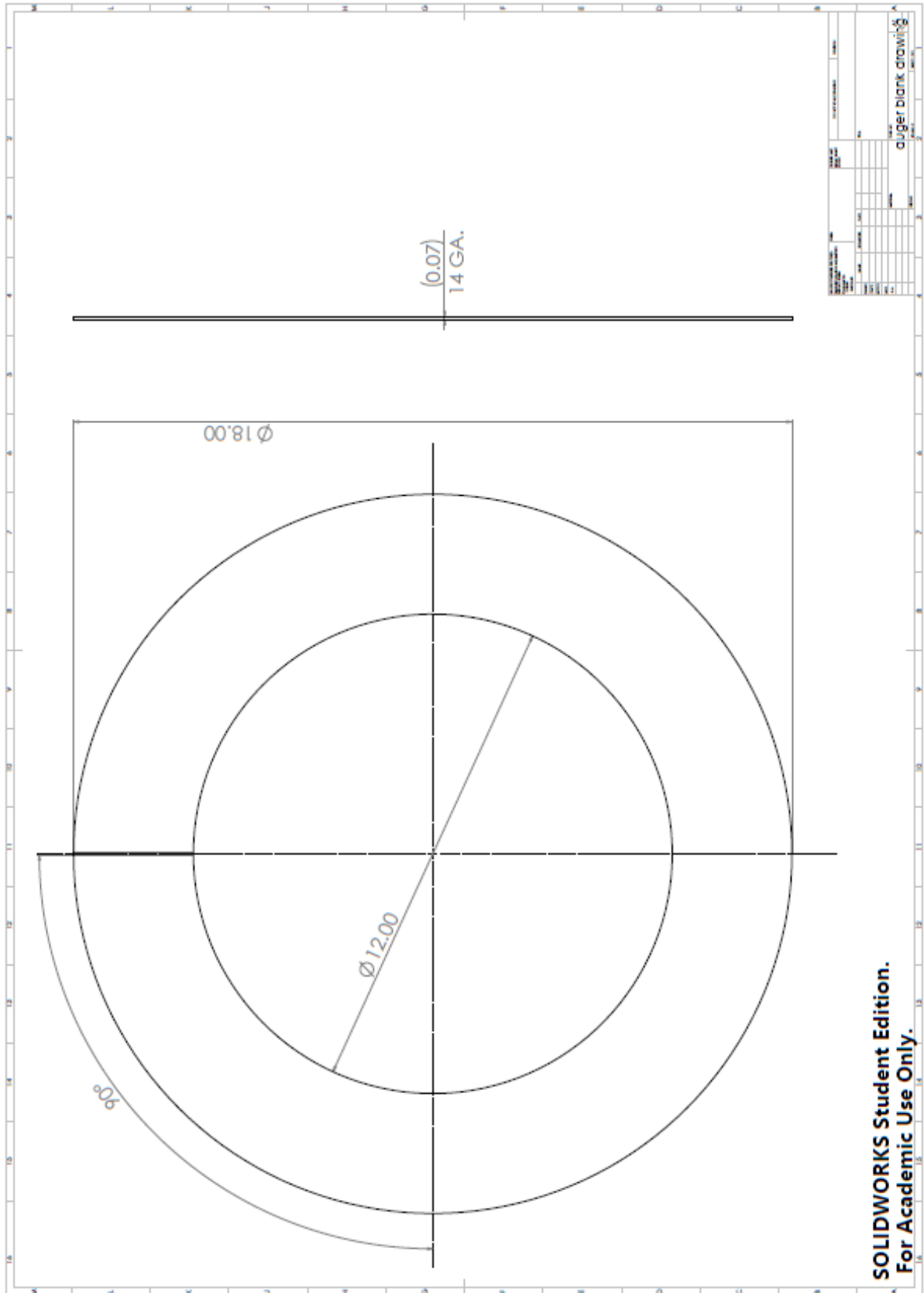
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Quotation for acceptance within 90 days
 Terms: VISA CARD
 F.O.B. GASTONIA, NC
 Delivery: 4-5 WEEKS

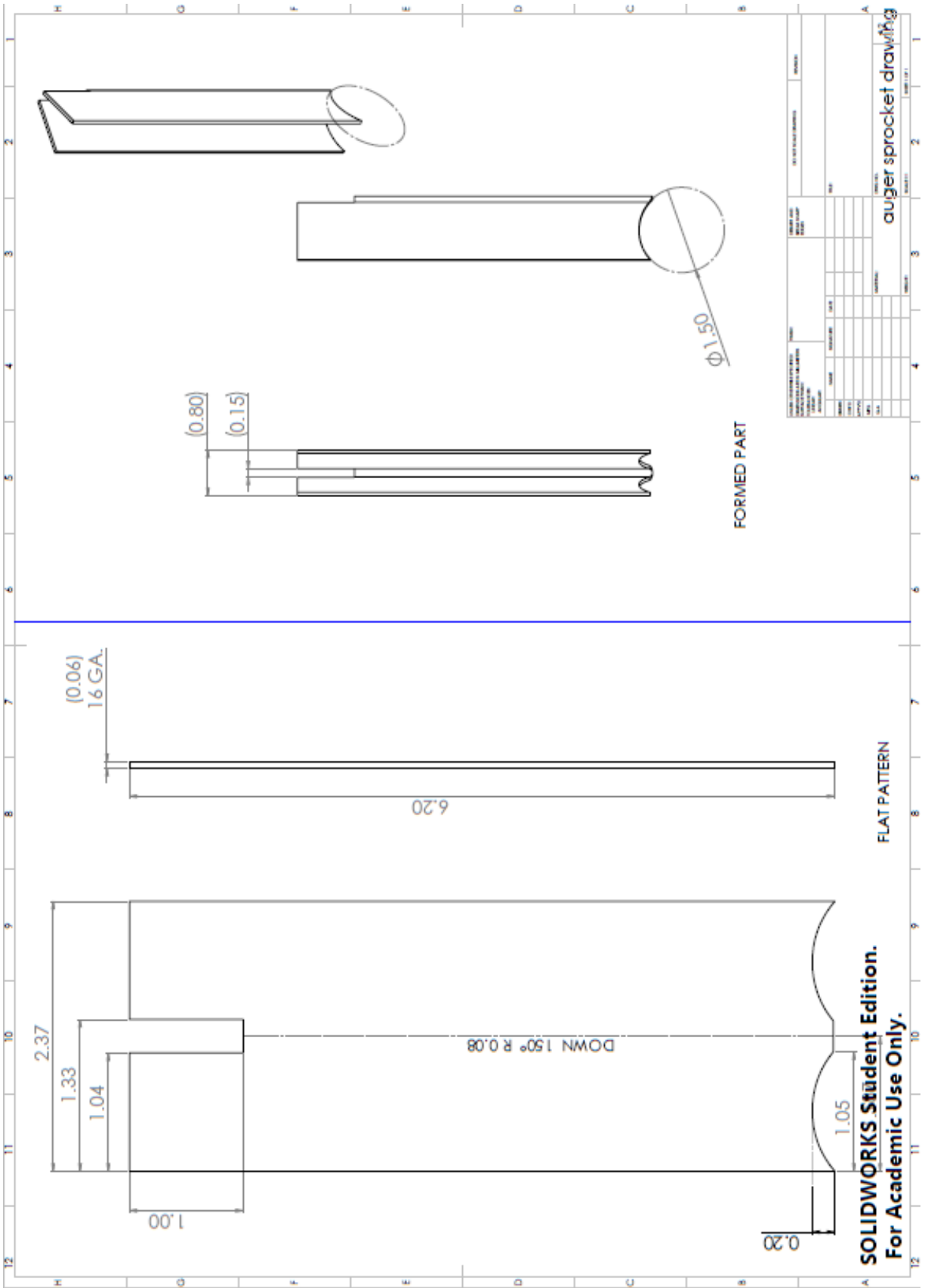
CAROLINA BRUSH COMPANY

Fred H. Spach, Jr.
 President

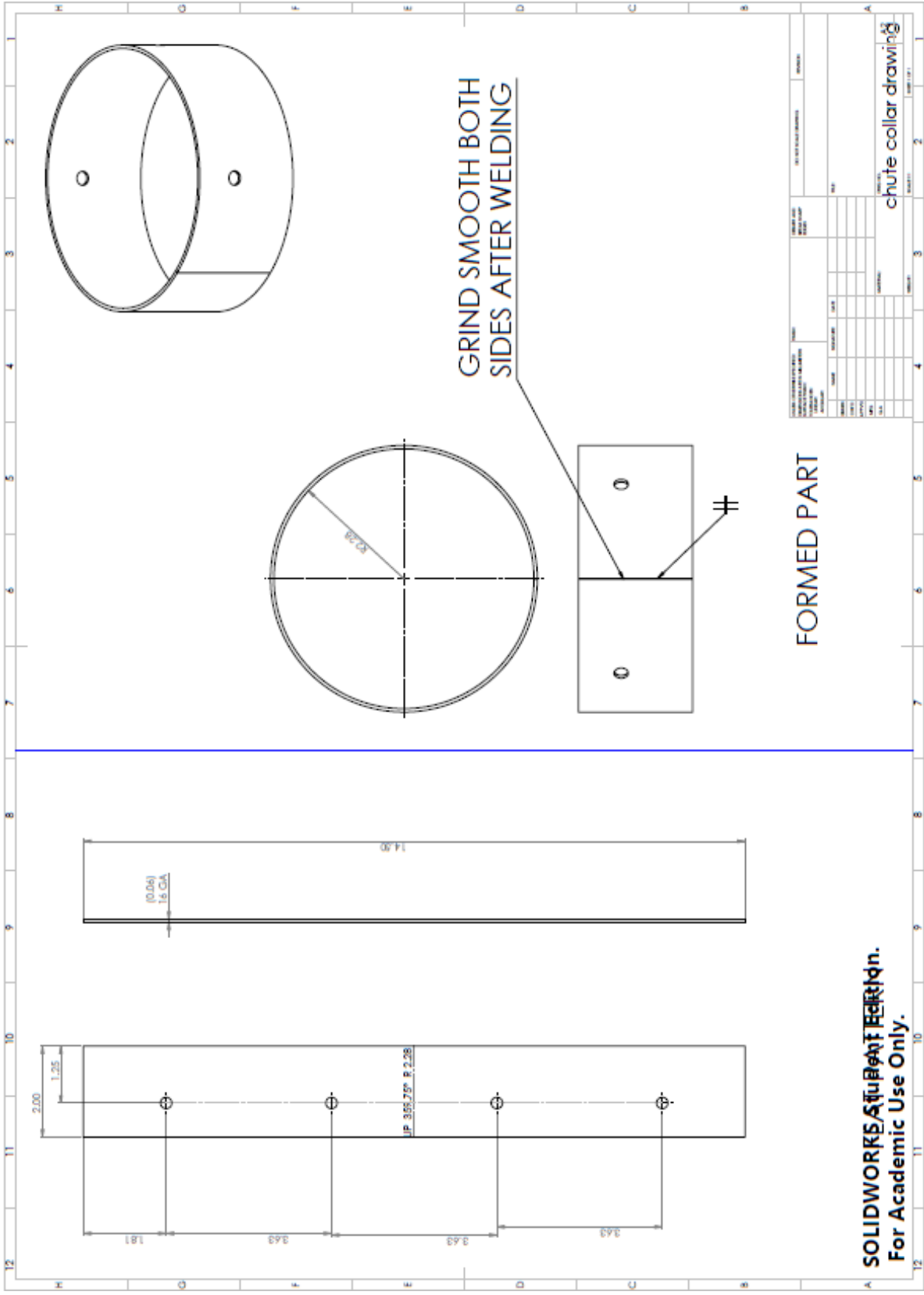
PARTS DRAWINGS



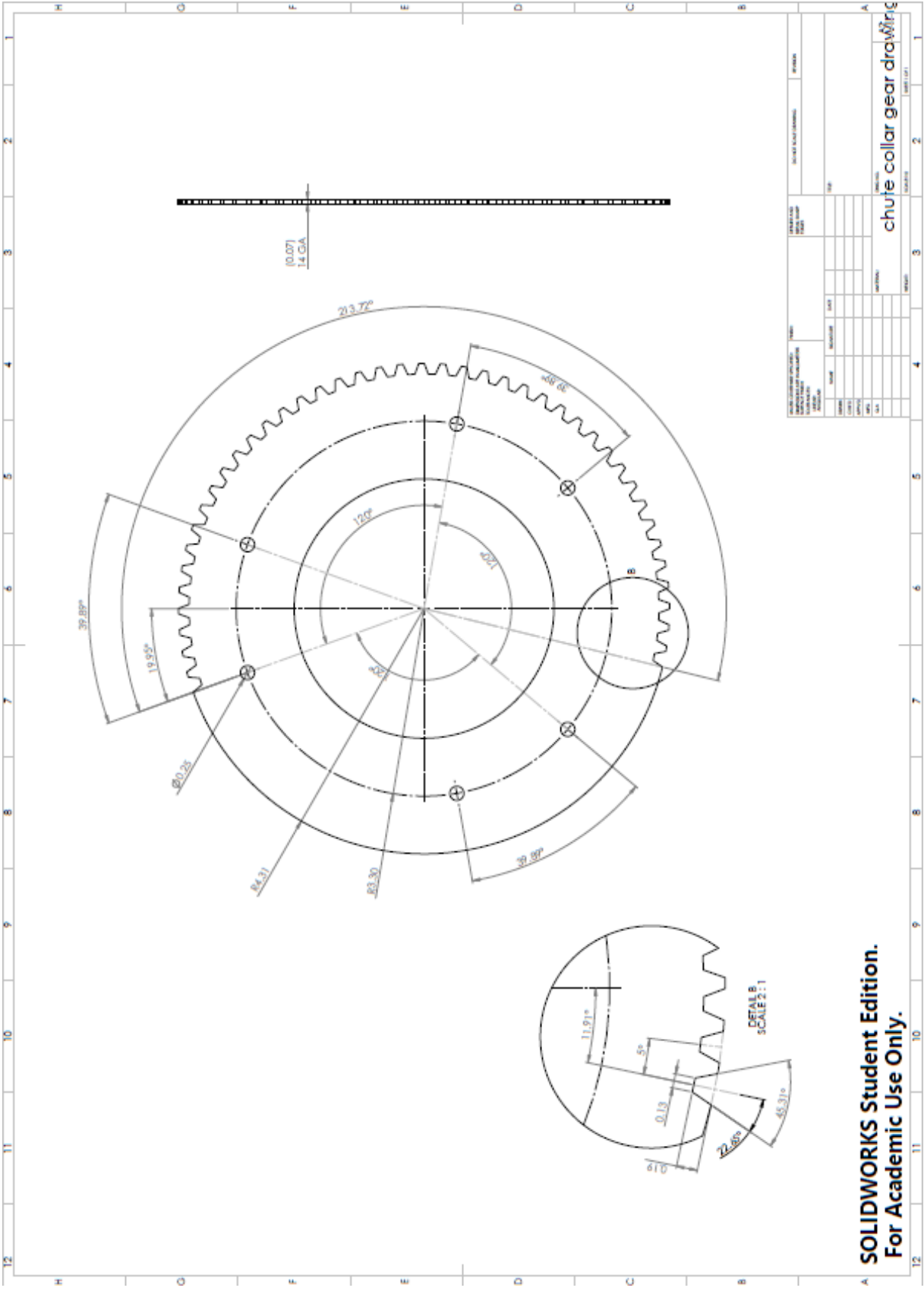
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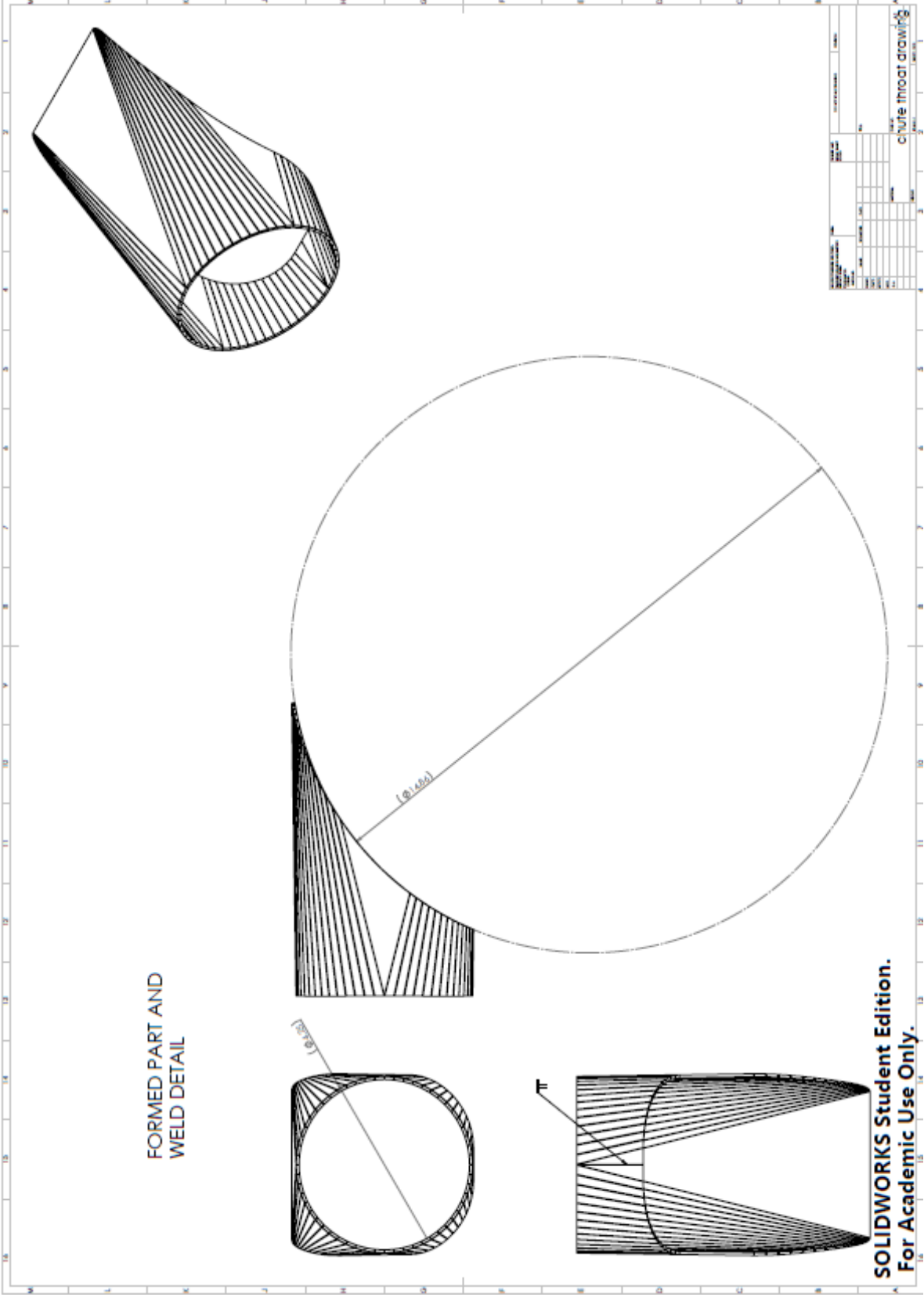
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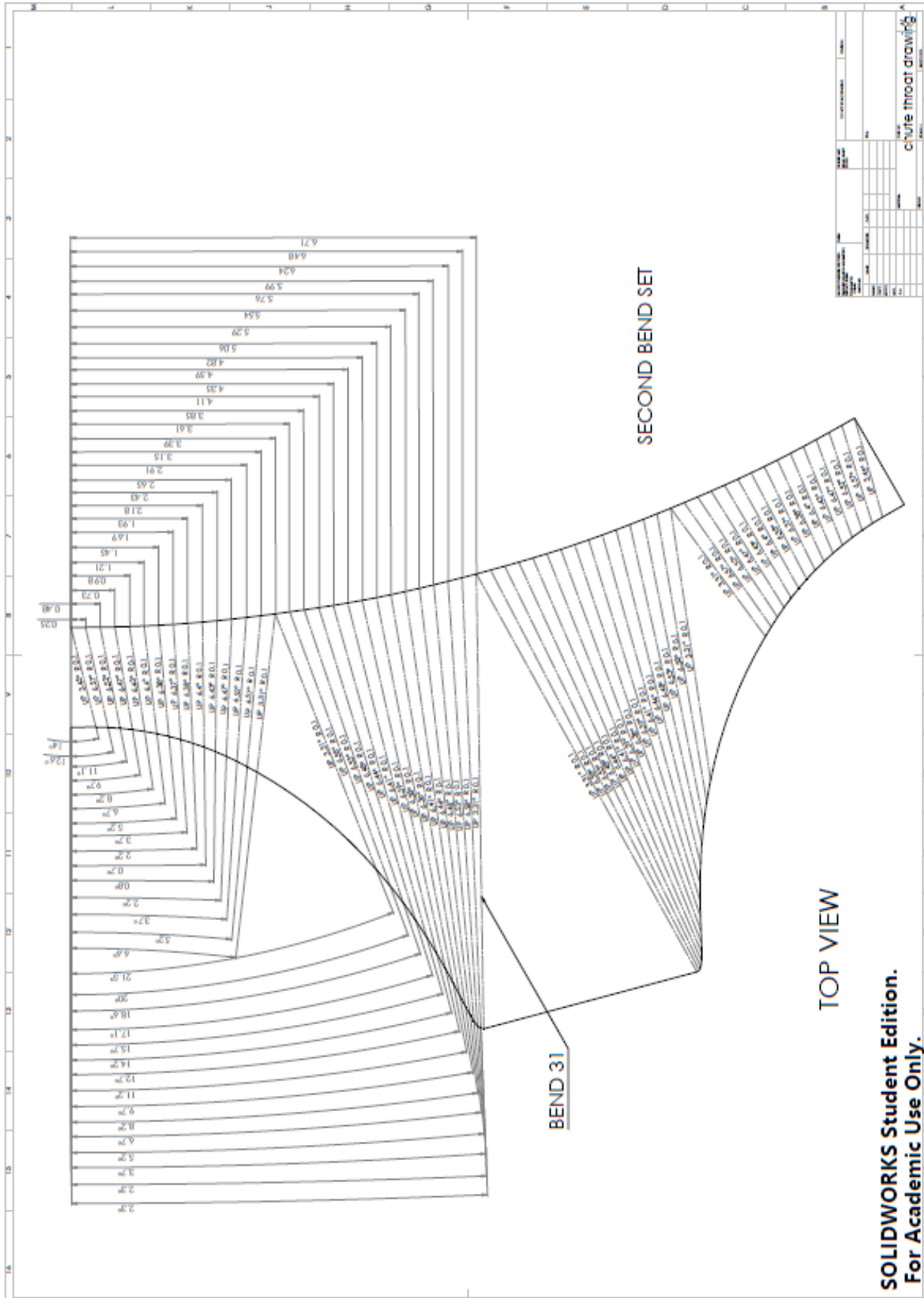
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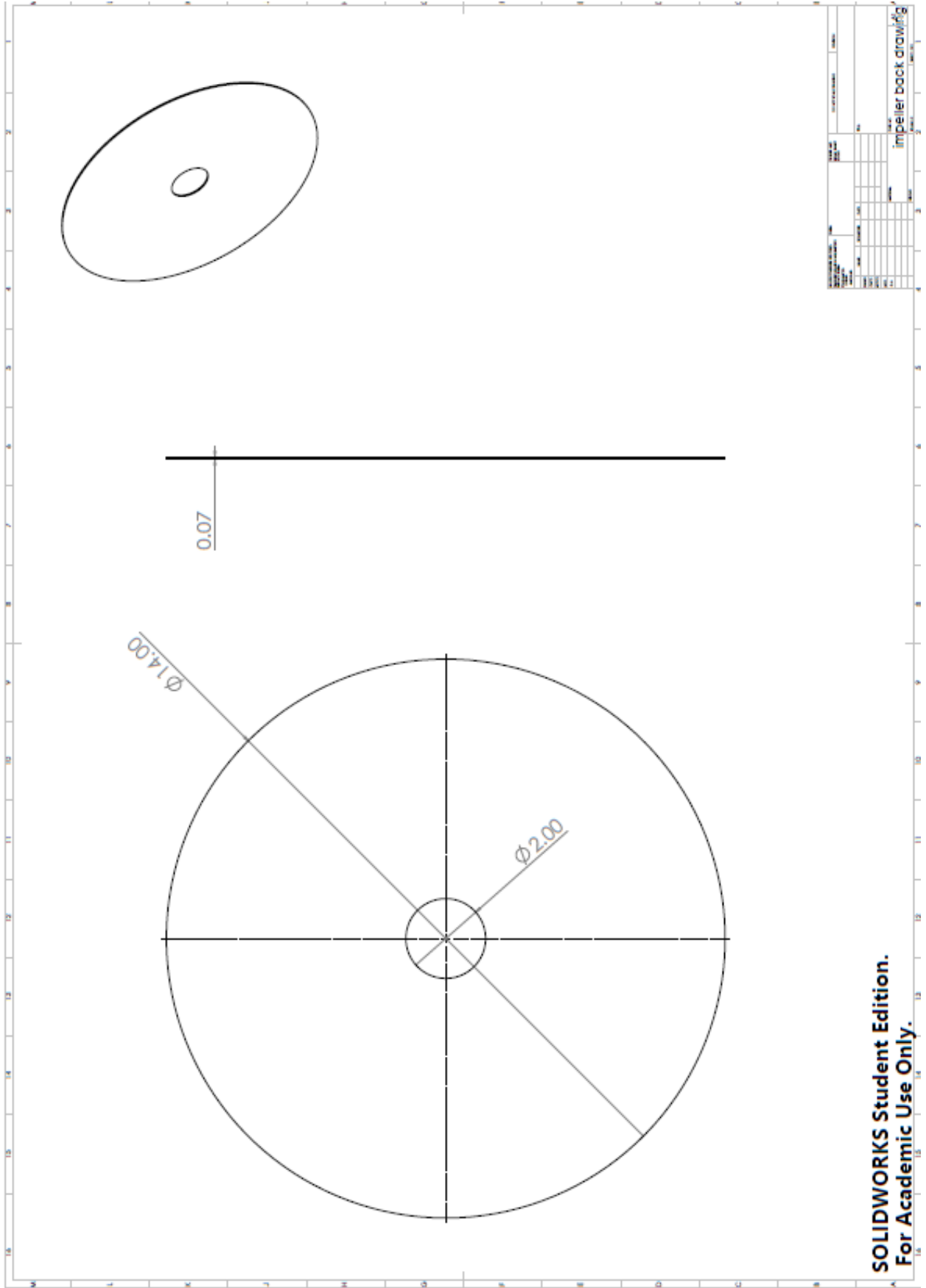
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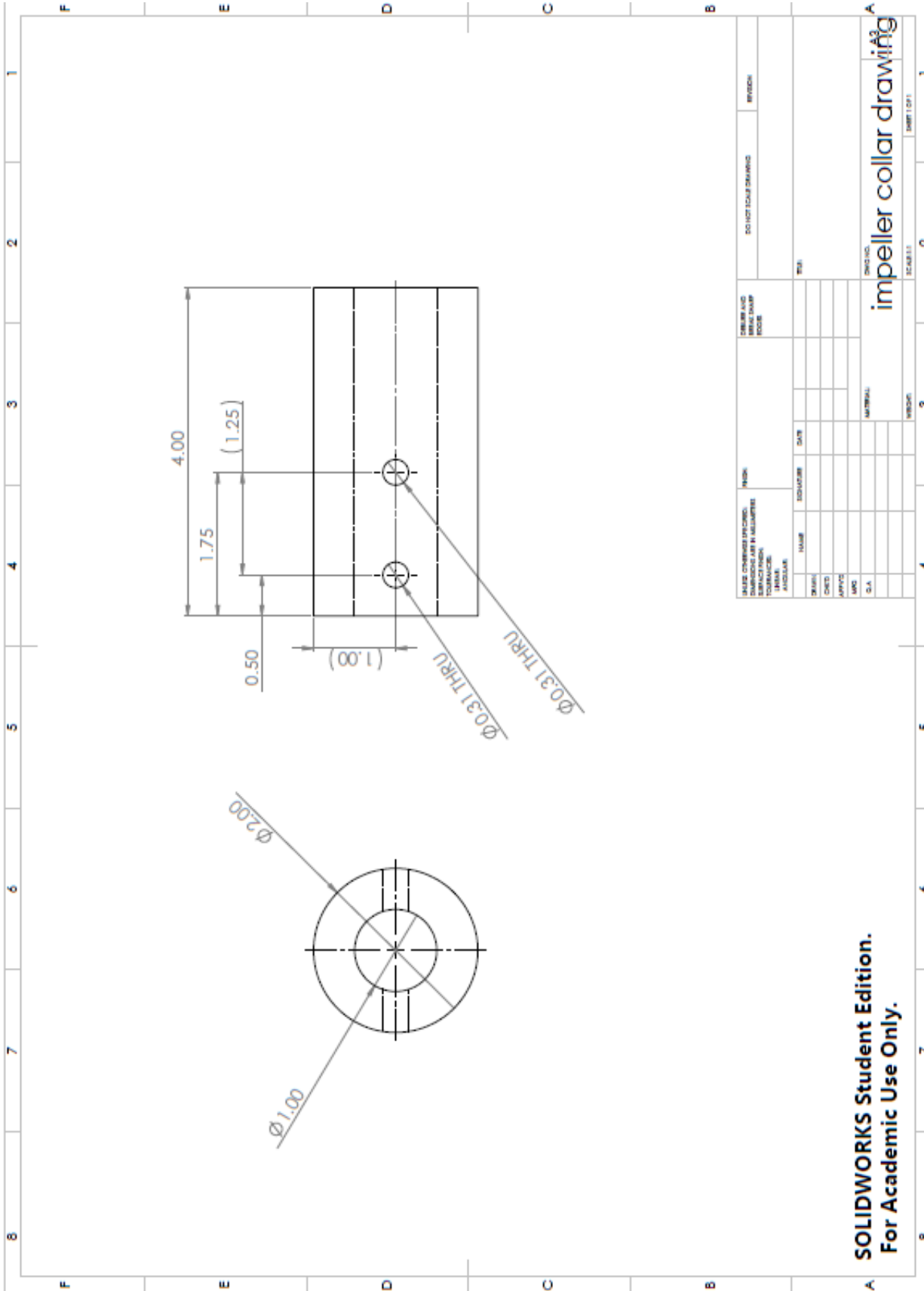
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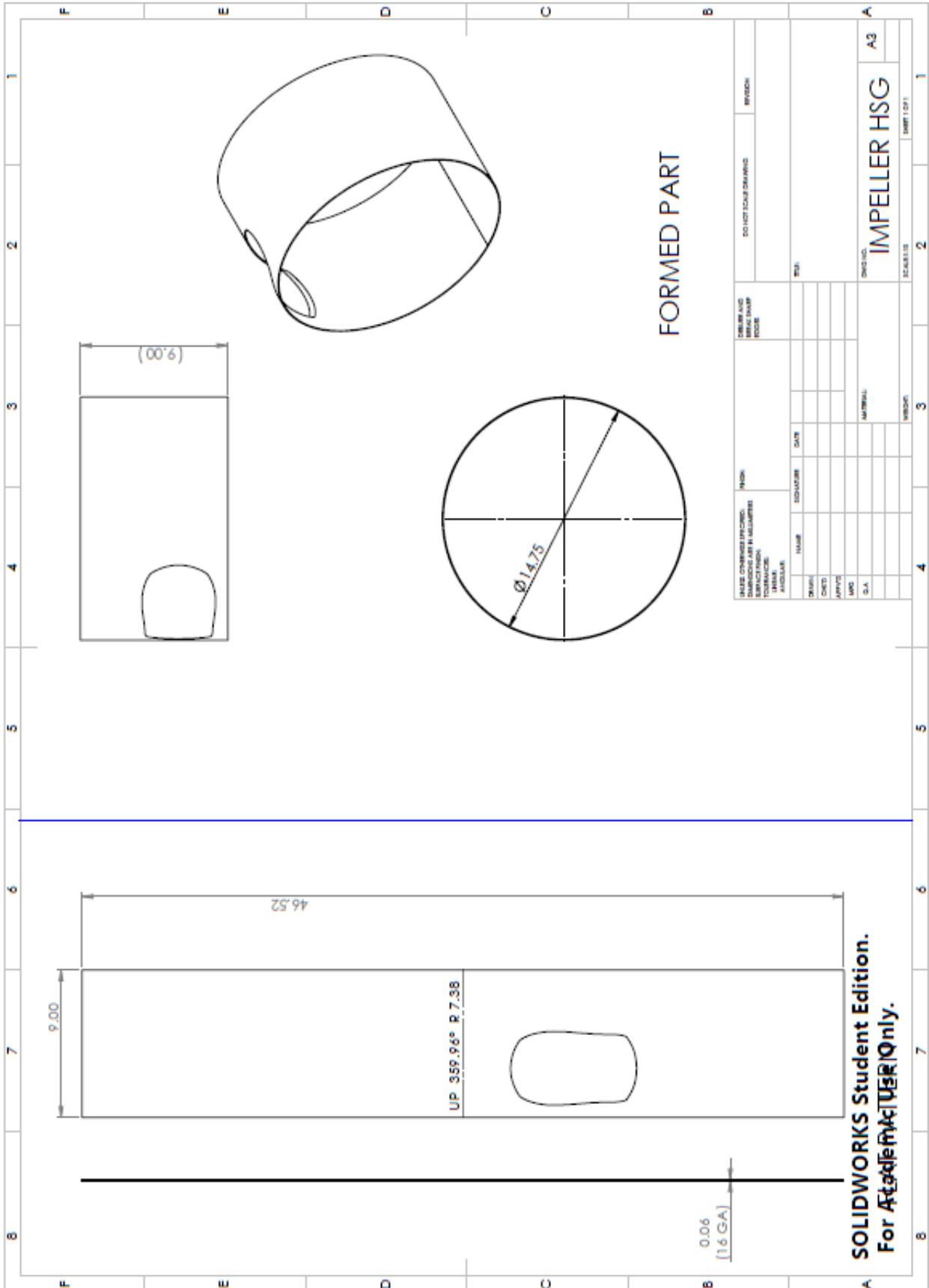
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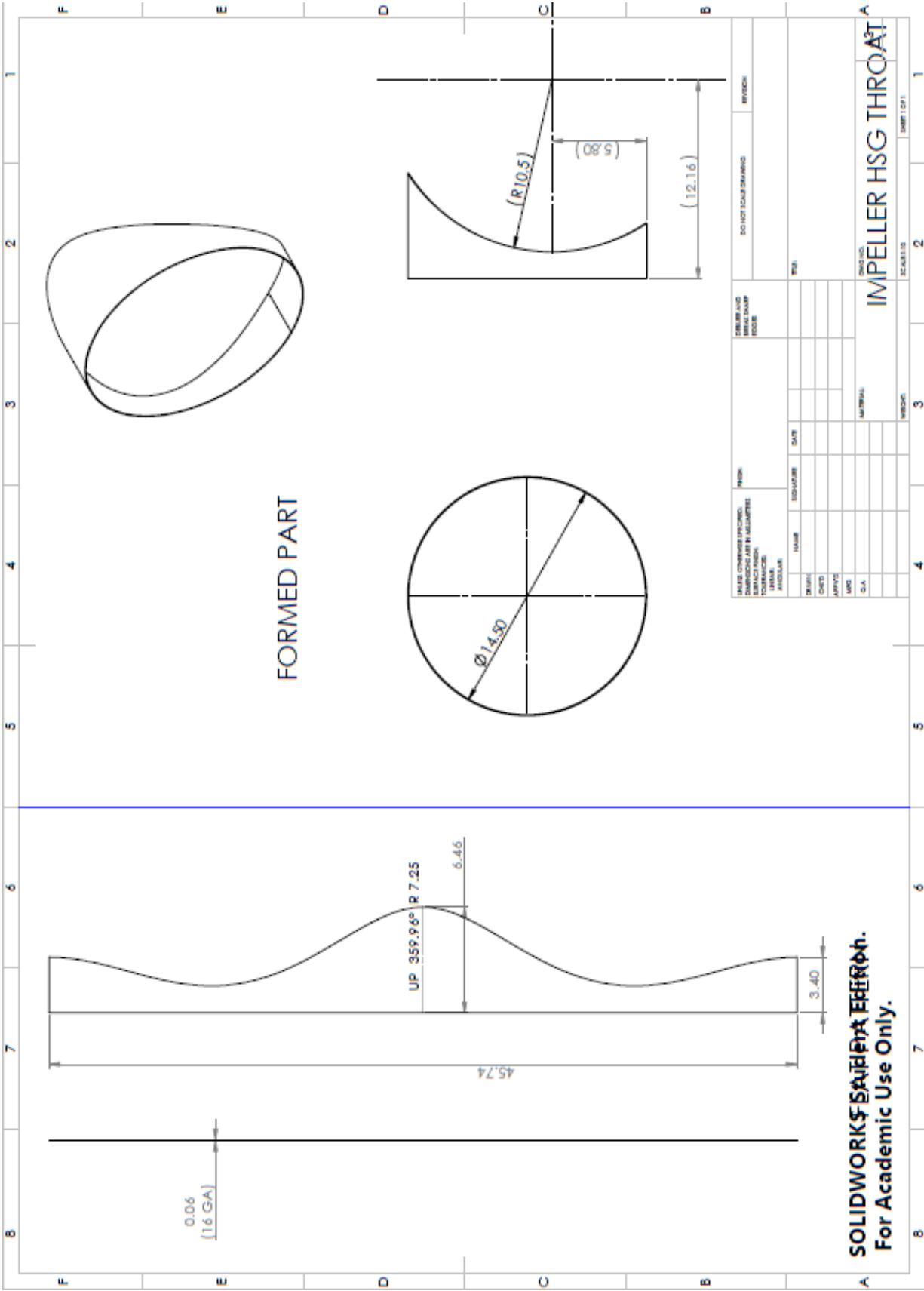


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DATE:	DESIGNED:	DATE:	ISSUE:		
CHECKED:	ENGINEER:	DATE:			
APPROVED:					
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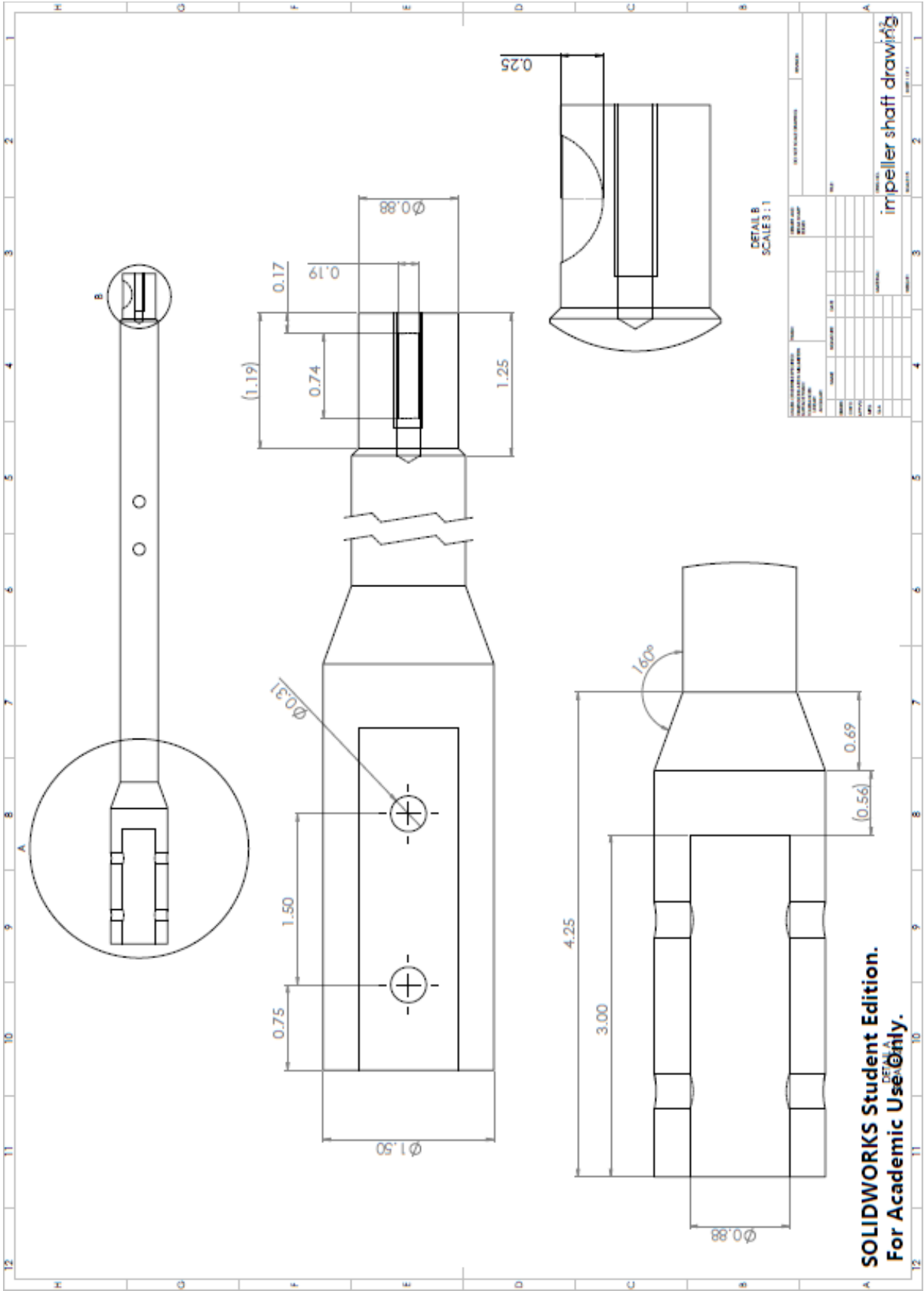
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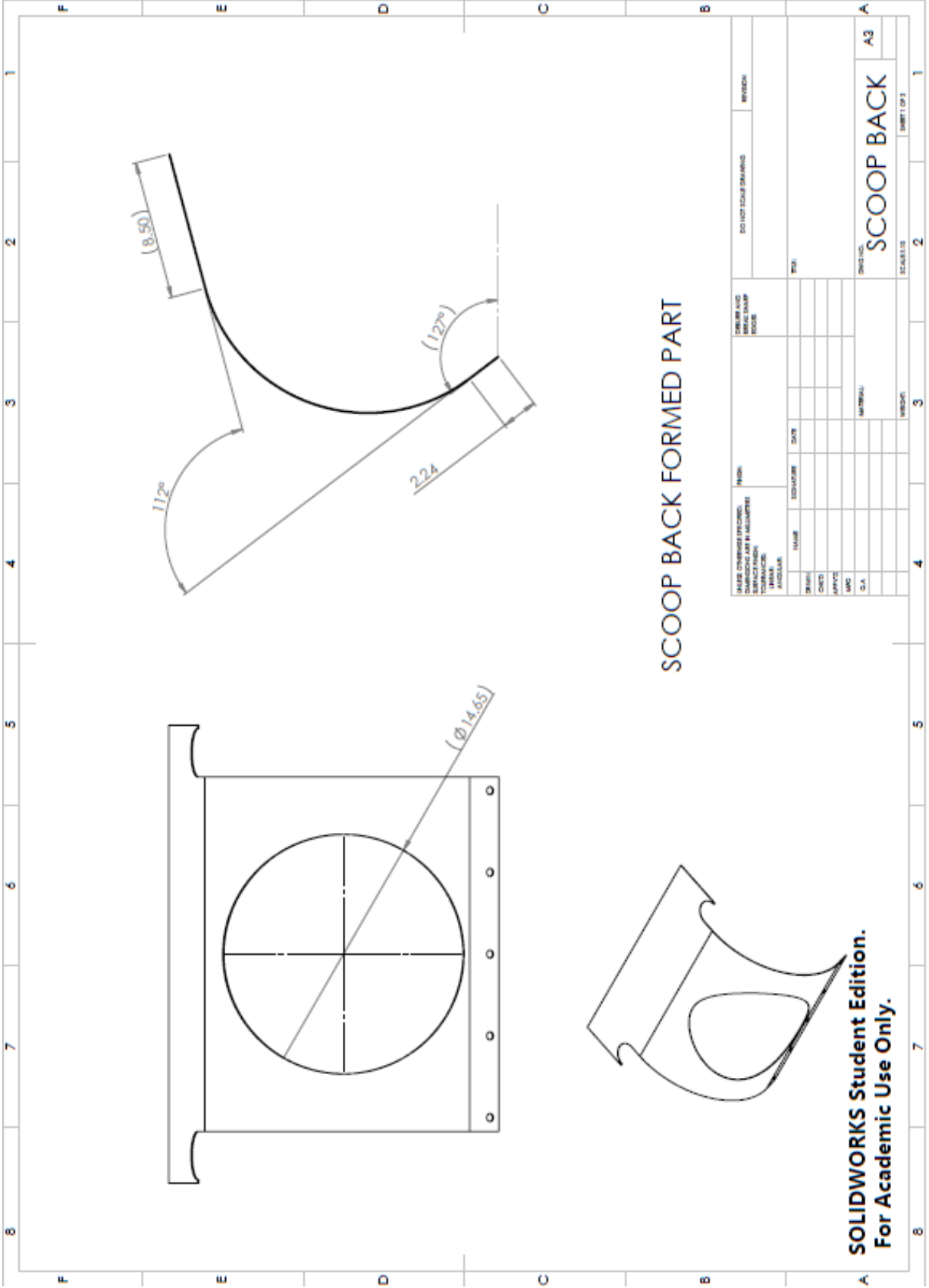
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DATE		SHEET NO.	
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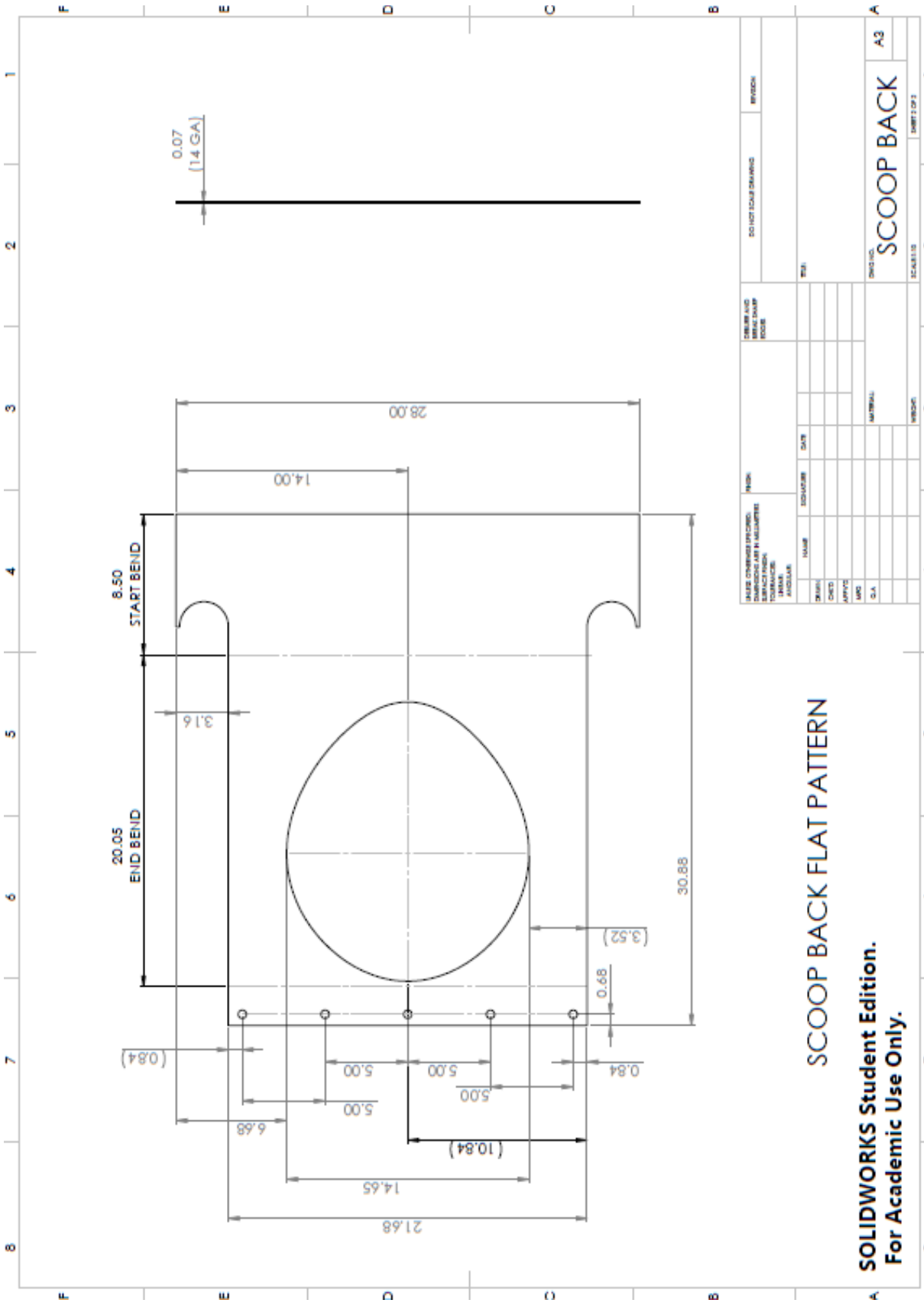
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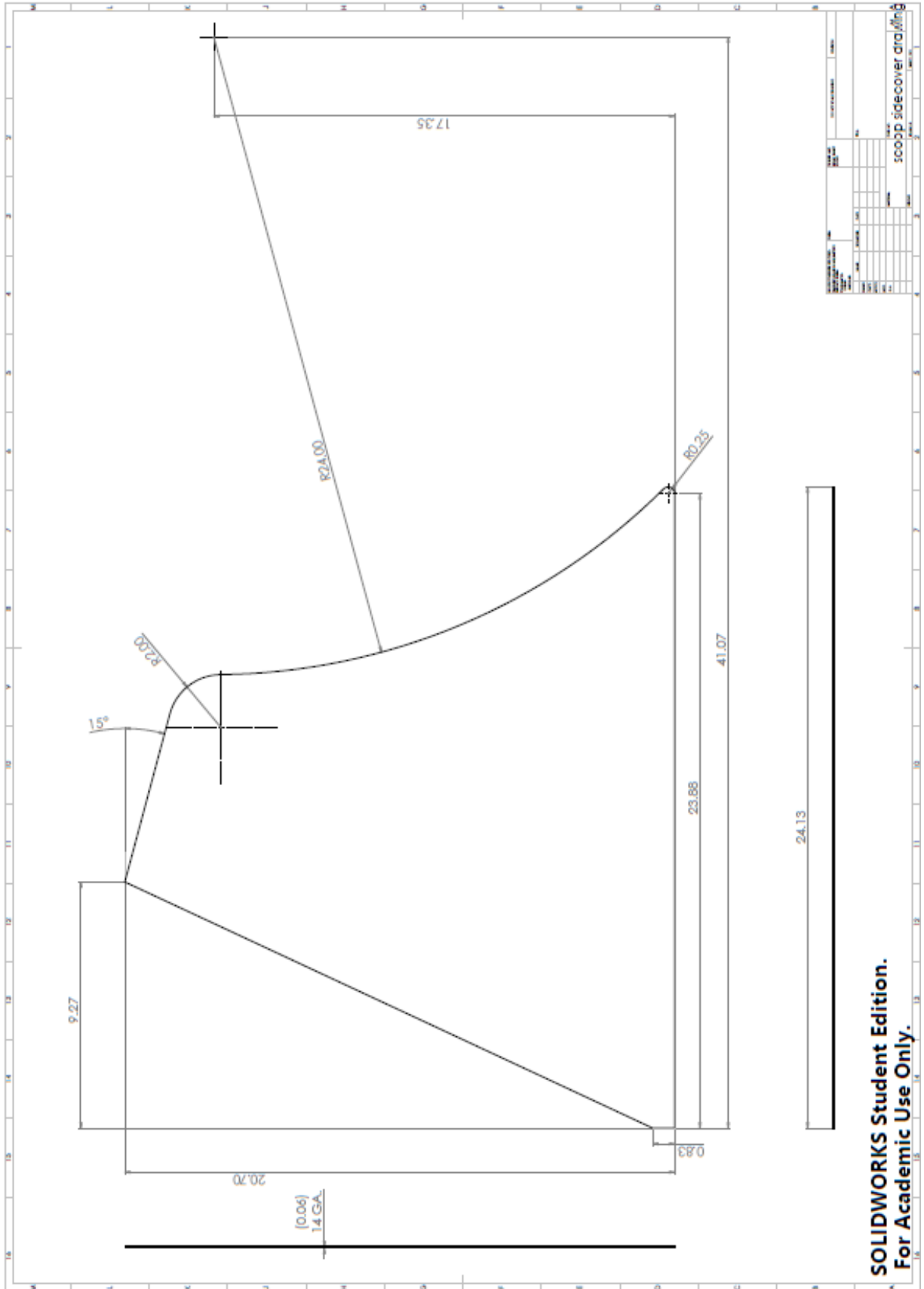


SCOOP BACK FLAT PATTERN

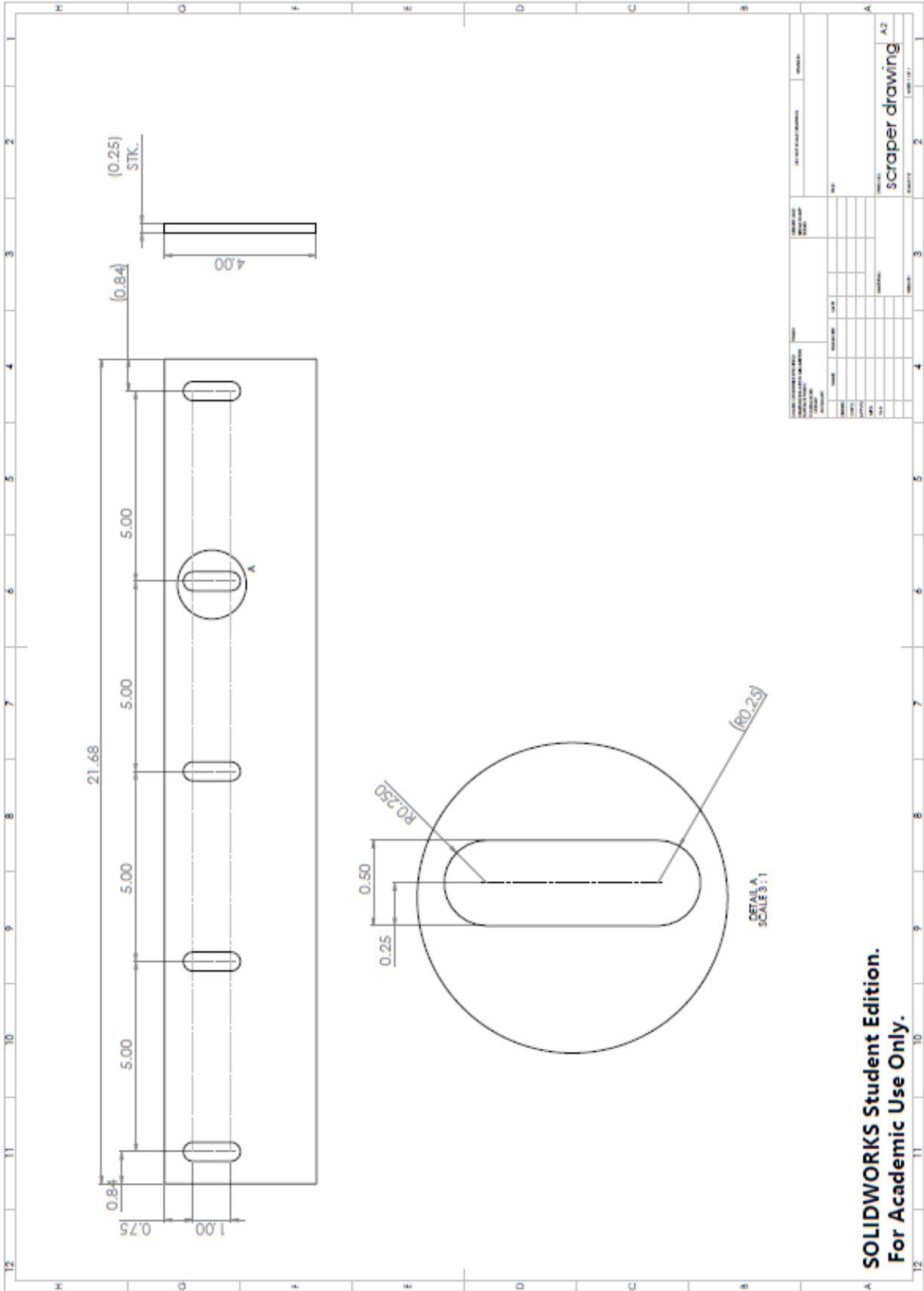
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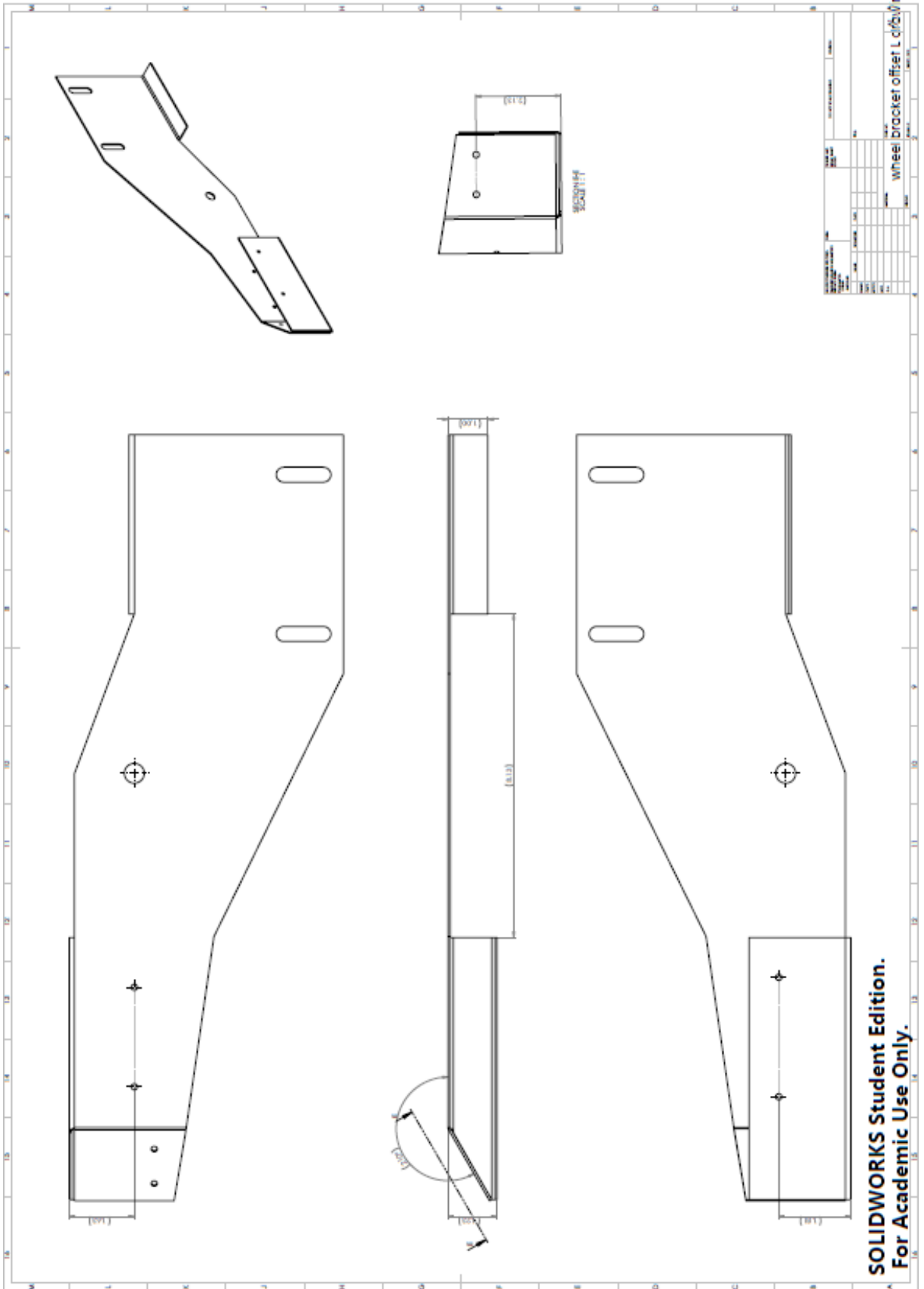
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 SHEET: **A3**



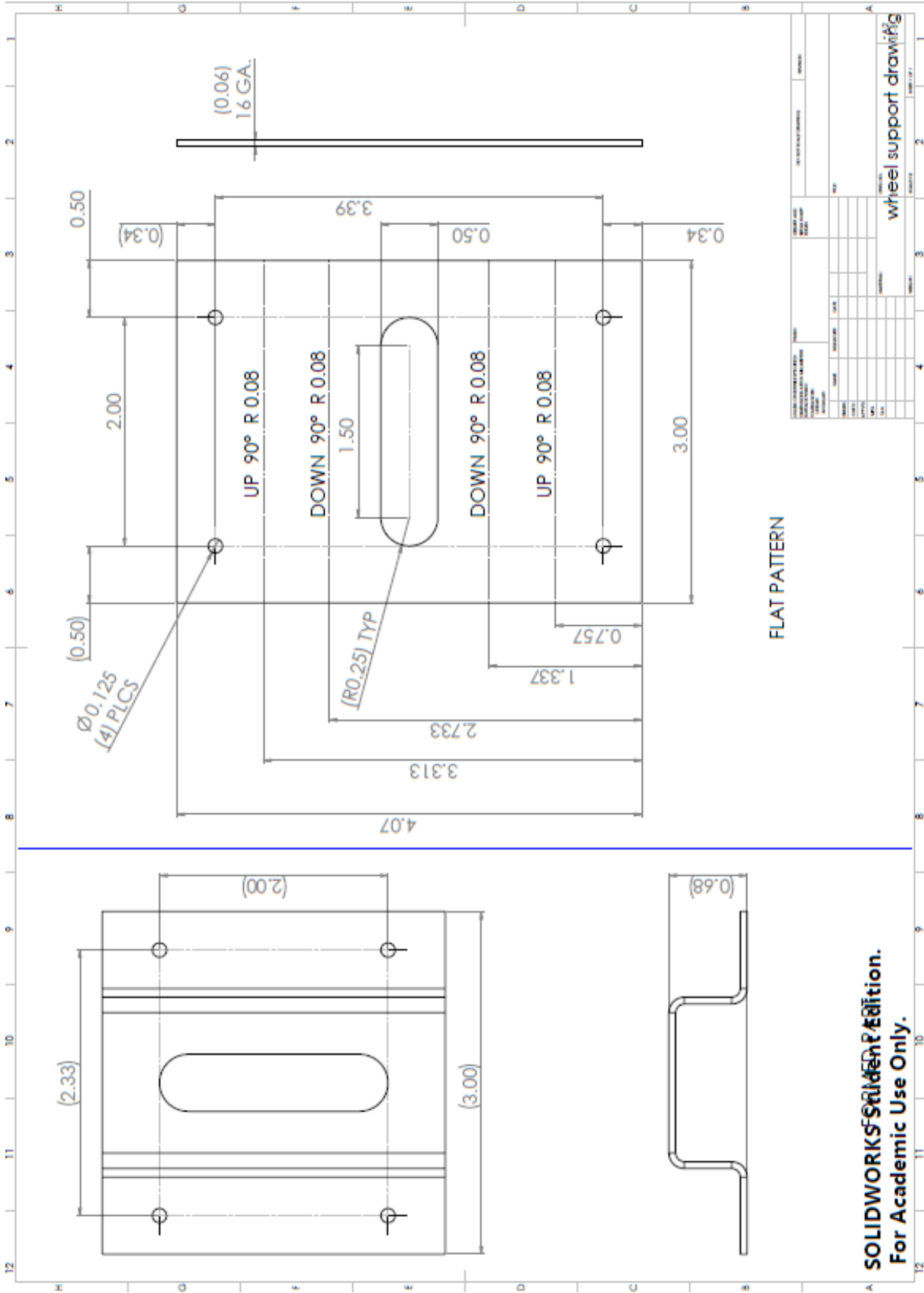
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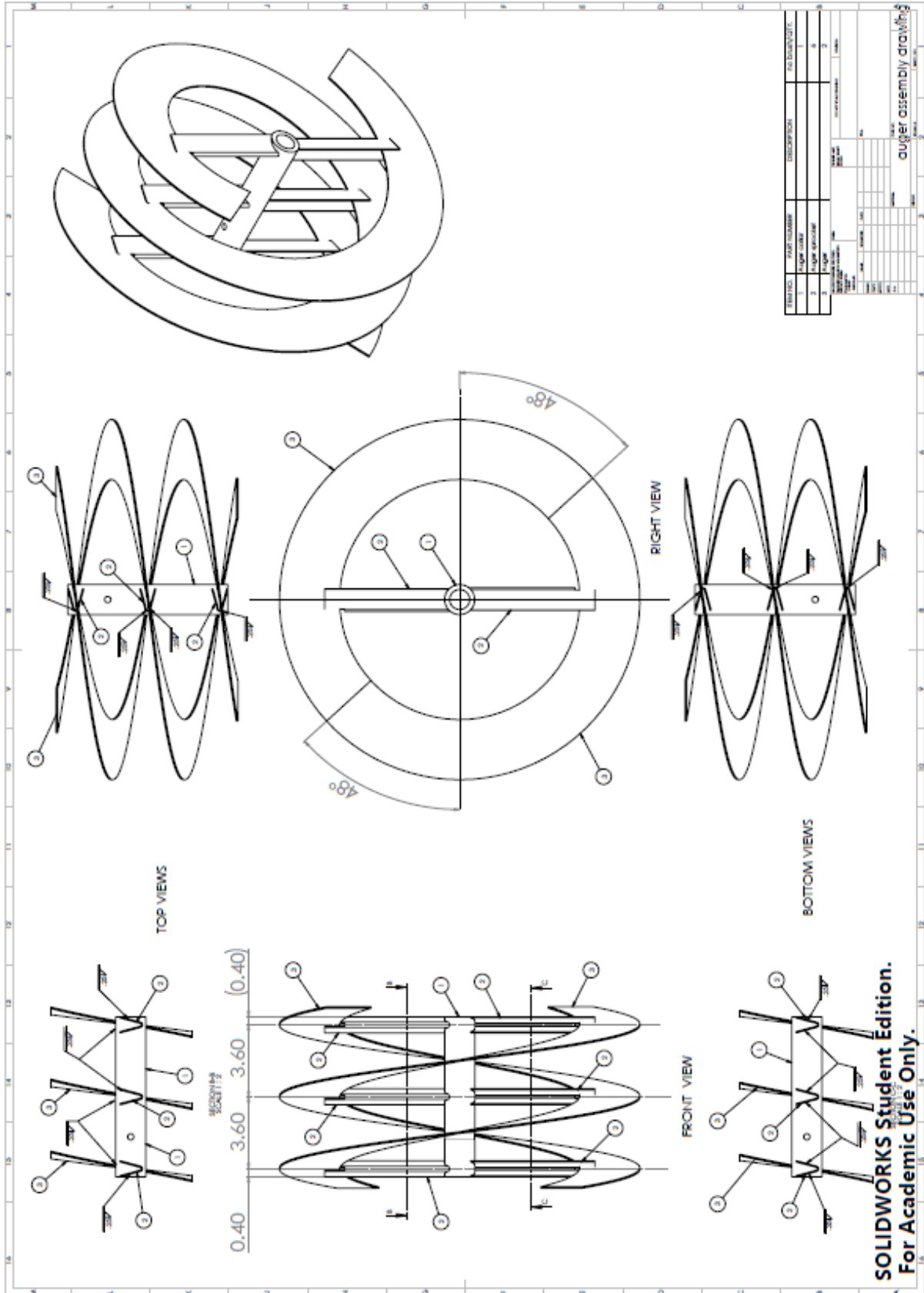
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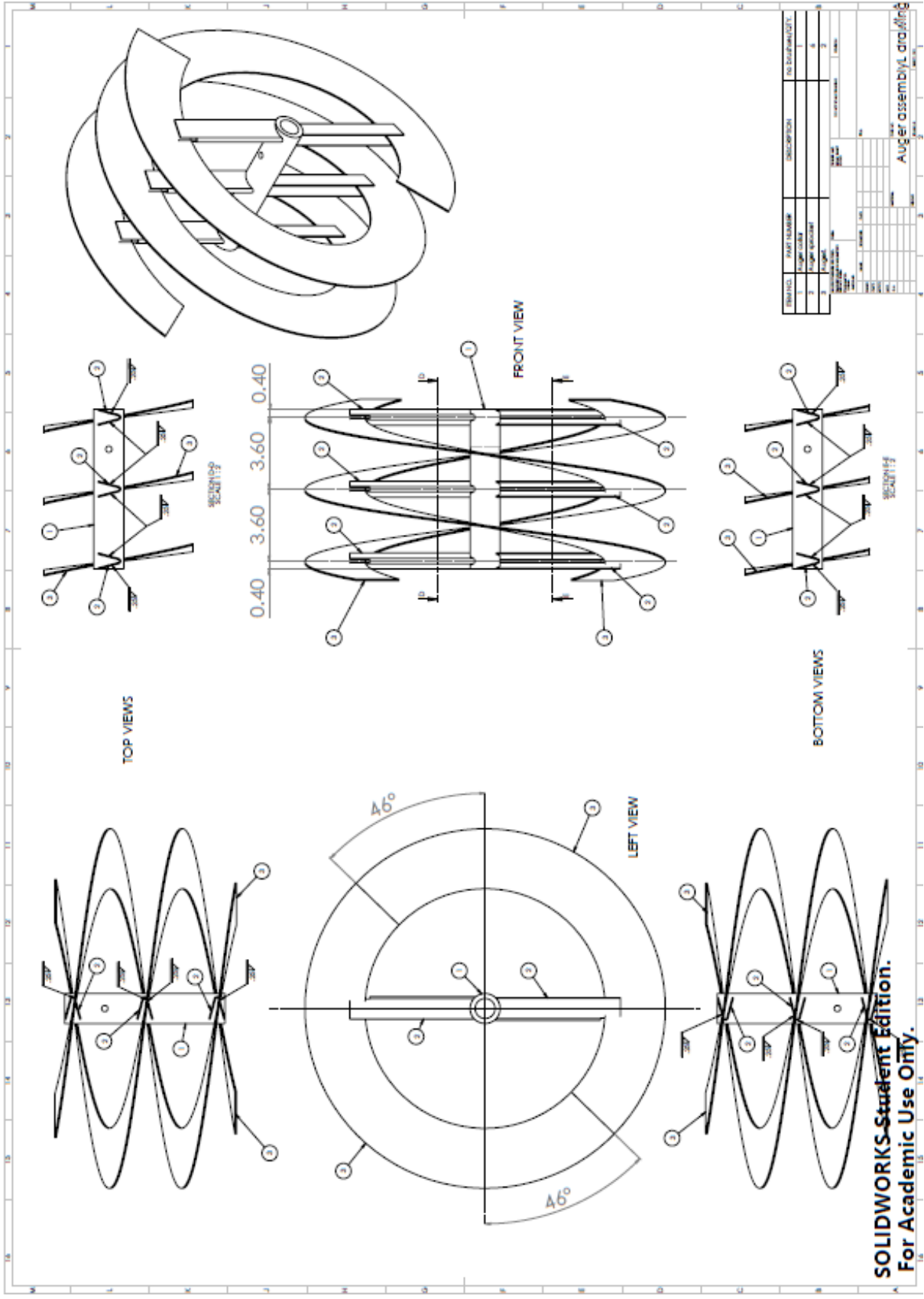
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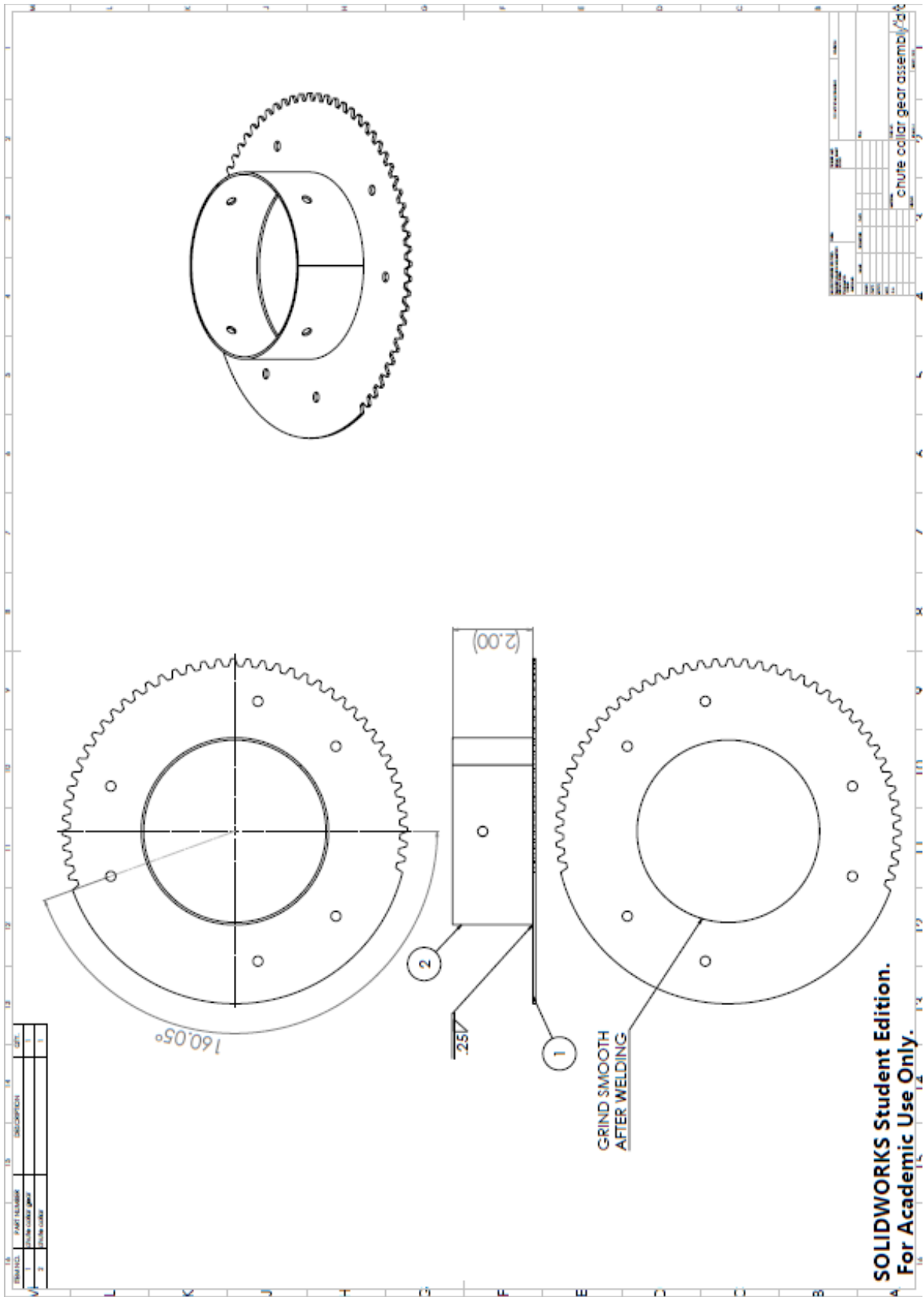


ASSEMBLY DRAWINGS

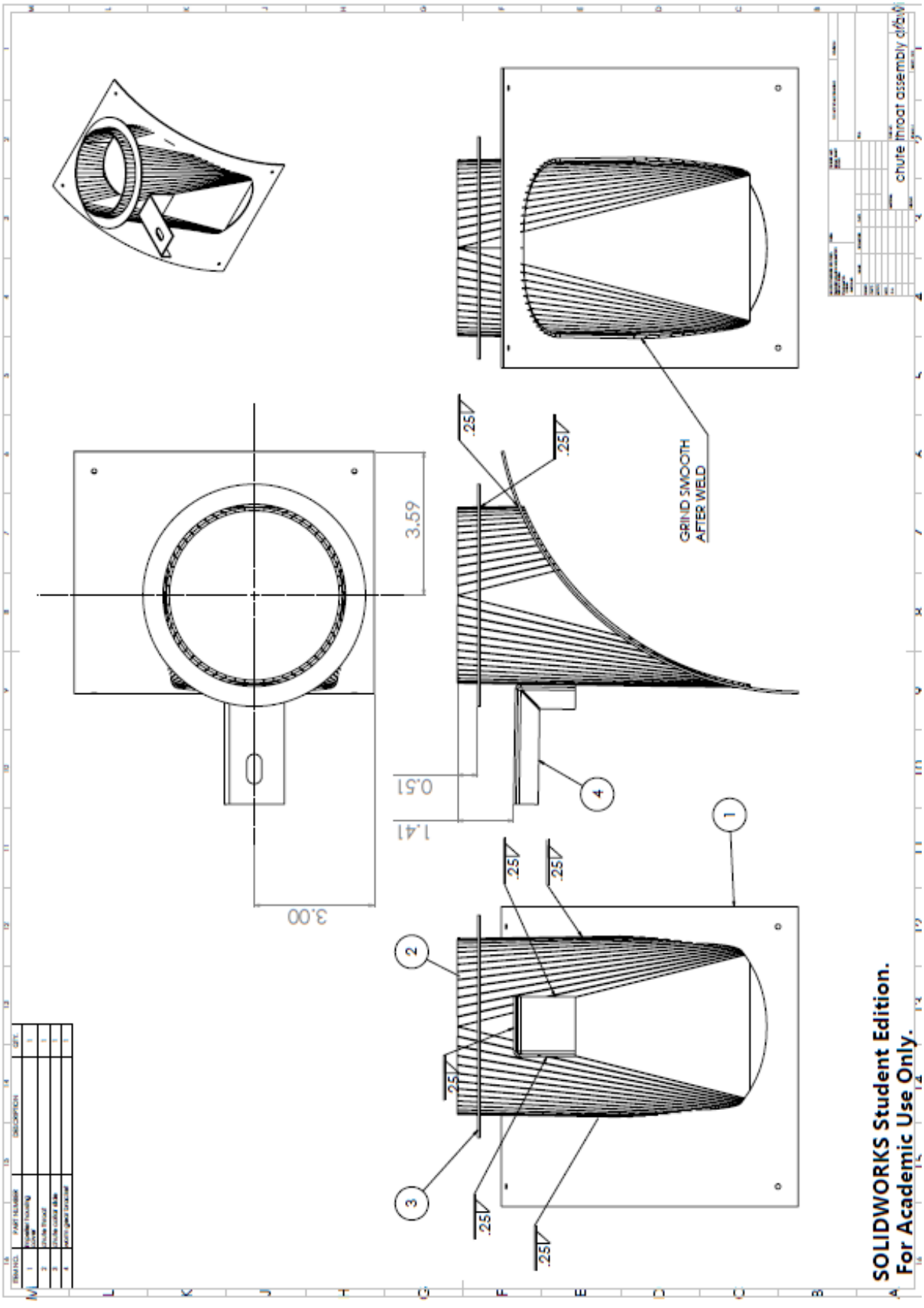


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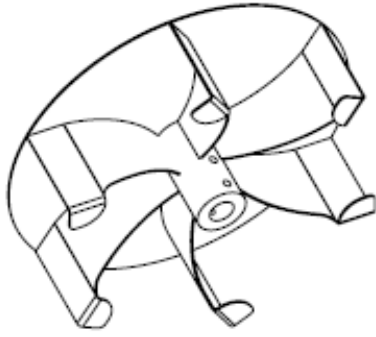
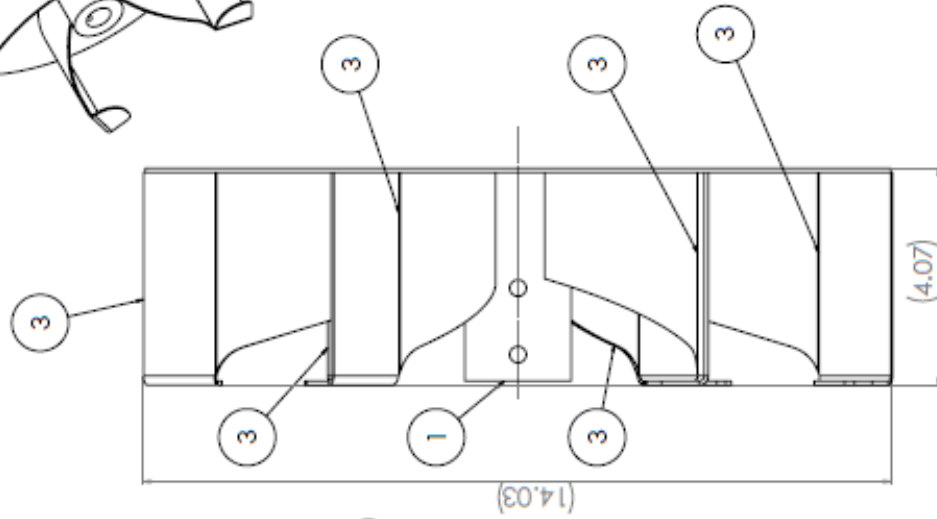
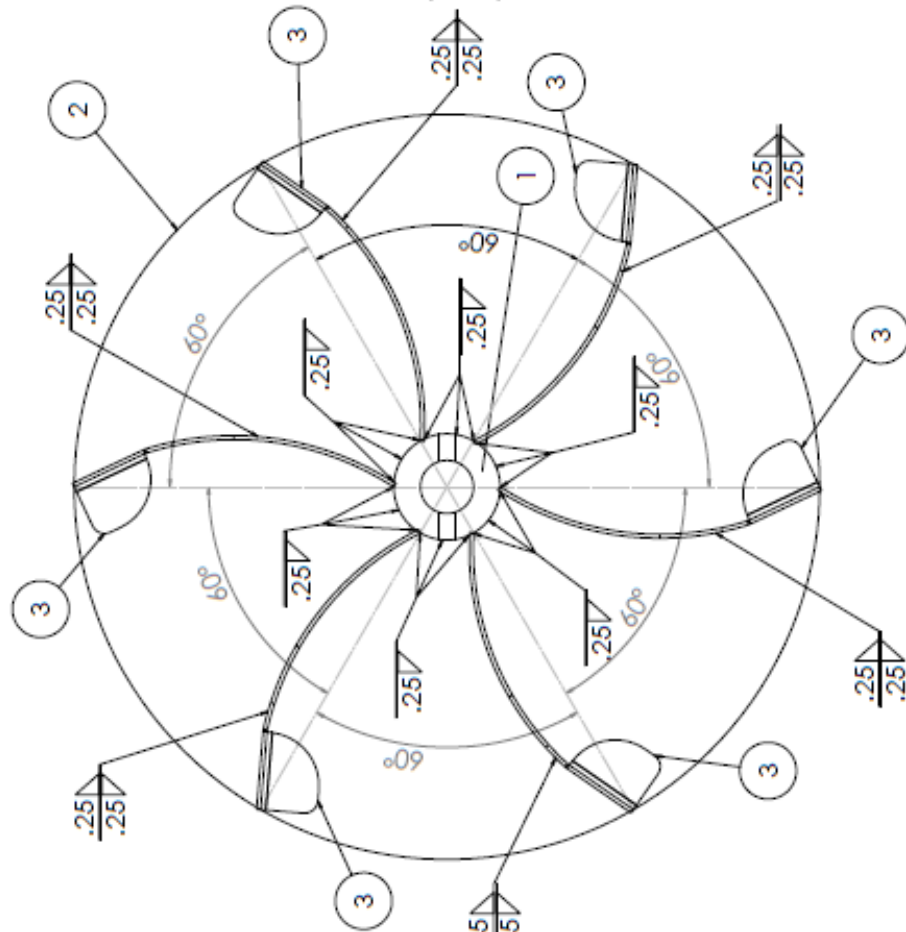
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ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	CHUTE THROAT	CHUTE THROAT	1
2	CHUTE THROAT	CHUTE THROAT	1
3	CHUTE THROAT	CHUTE THROAT	1
4	CHUTE THROAT	CHUTE THROAT	1

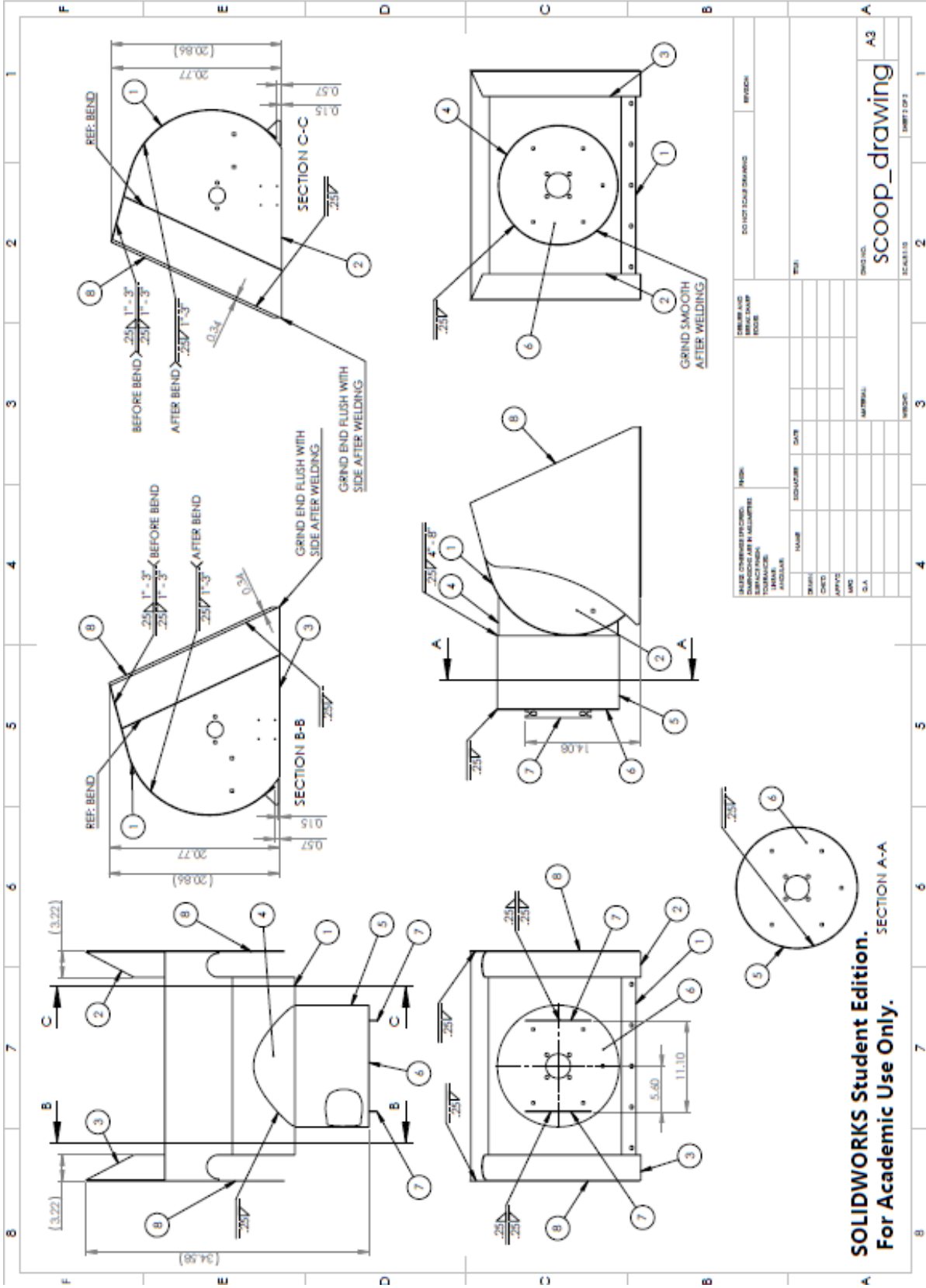
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ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	impeller collar		1
2	impeller back		1
3	impeller blade		6

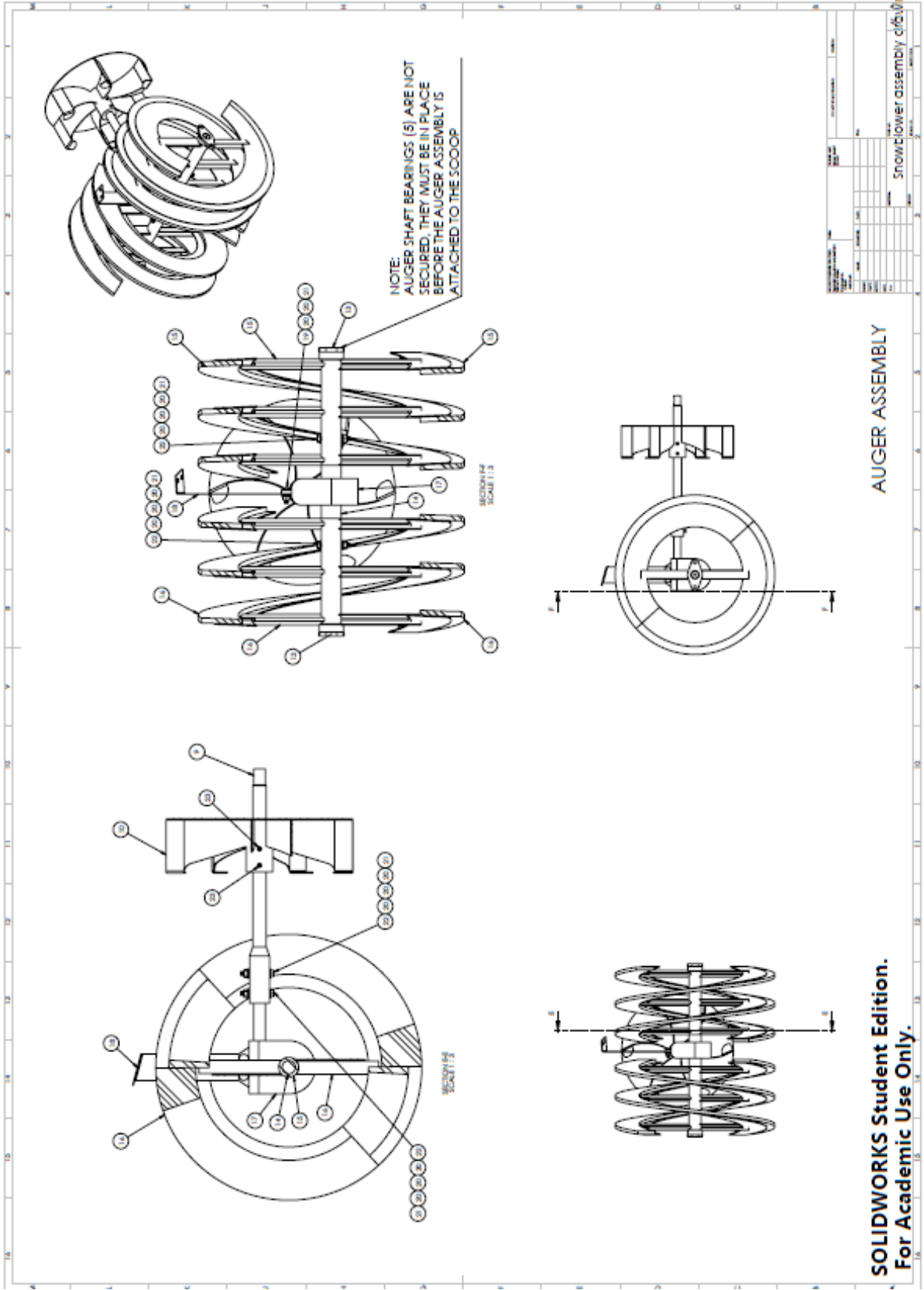


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1		impeller assembly drafting

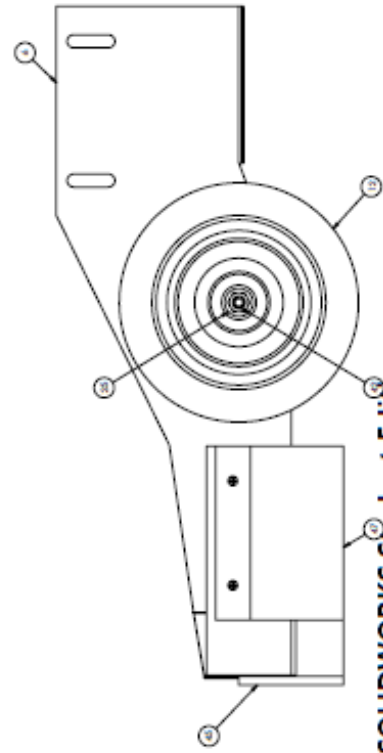
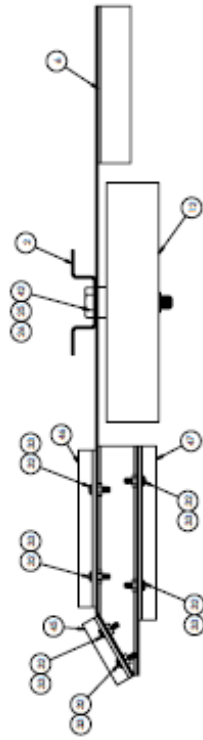
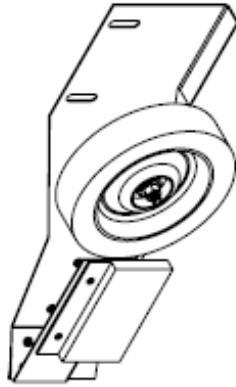
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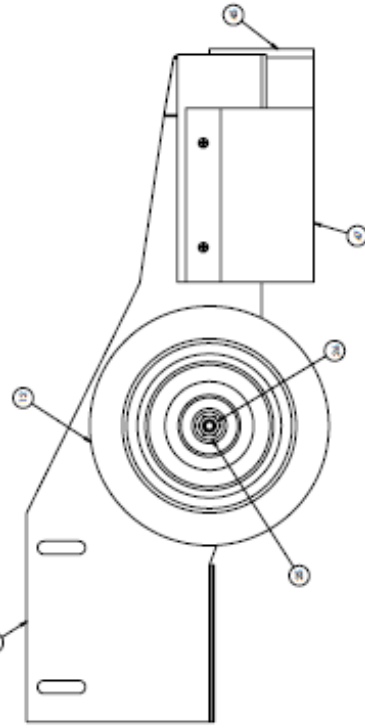
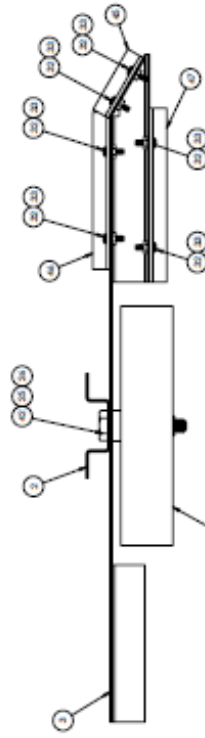
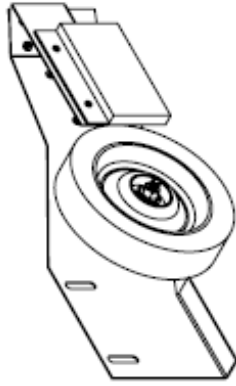
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LEFT WHEEL BRACKET ASSEMBLY



RIGHT WHEEL BRACKET ASSEMBLY



REV	DATE	DESCRIPTION
1		Initial Release
2		Revised for Assembly

Part Name: snowblower assembly.dwg
 Part Number: 1000000000

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