



# F1 in Schools Car Design Advanced Tutorial

**Abstract:** Gain tips for modeling your own F1 car design from scratch and build on the skills learned in using the Autodesk Inventor F1 in Schools Car Design Intermediate tutorial. Understand design options if you are using a 4-axis CNC approach. Get tips on modeling your own wheel designs and calculating the mass of a model.

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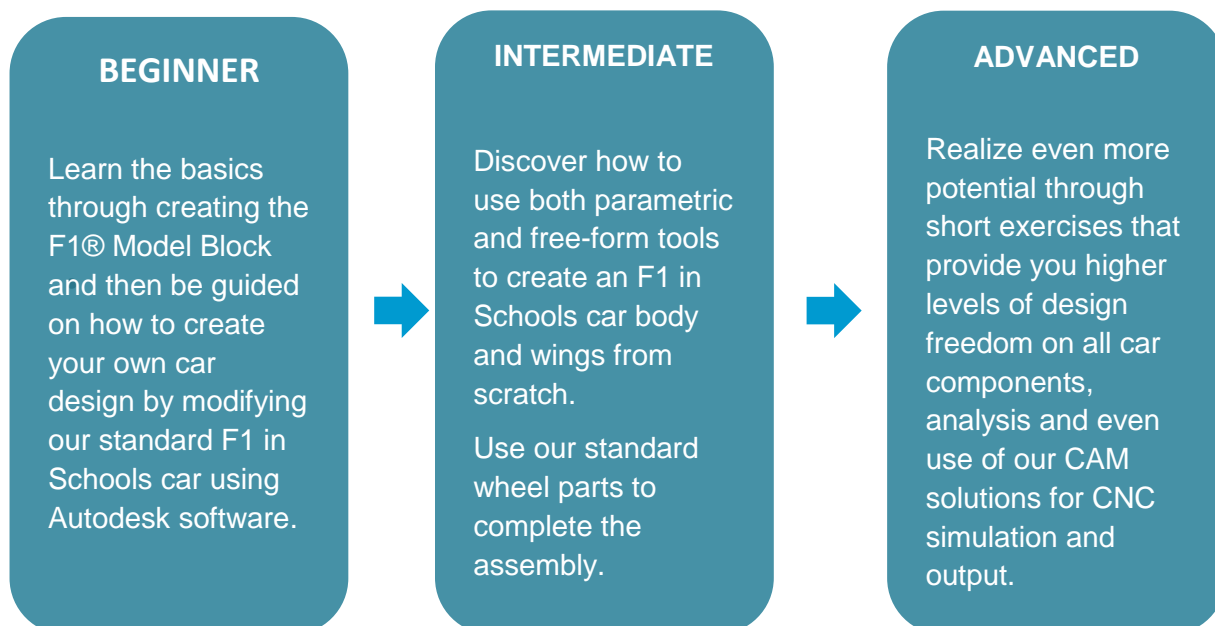
## Introduction

Congratulations on choosing to work through the Autodesk Inventor F1 in Schools™ Car Design tutorials. Ideal for both first time F1 in Schools car designers and more seasoned car designers, these Autodesk Inventor tutorials are designed to get you up and running with the software quickly and effectively so you can have a car ready for manufacturing in record time. Start designing tomorrow's fastest F1 in Schools car the fastest way now!

With these tutorials, you will:

- Get effective results faster – use the beginner tutorials to learn the software basics by simply modifying an existing car design to produce your own unique styling ready for manufacturing quickly and successfully.
- Understand the F1 in Schools car body manufacturing process and improve your designs accordingly. Design your car body ensuring it is suitable for CNC manufacturing.
- Save time by having access to a library of standard F1 in Schools car accessory part files, including the standard wheels, axle system and tether guides.
- Get tips for how to ensure your car body fits the dimensions of the official F1 Model Block.
- Design your car so it has separate front and rear wing parts, fully integrated with the body design, prepared ready to export for manufacturing on a 3D printer.
- Be reminded about F1 in Schools design regulations and how to check compliance as you are designing in 3D
- Extend your skills through quick tips and exercises in our advanced tutorials related to wheel design and other features, such as design mass calculation, designing in 3D from a hand sketch, and CAM using Autodesk solutions.
- Use our new Autodesk Flow Design tutorial to analyze the aerodynamic performance of your design in 3D and make tweaks during your design development stages. Be guided in the use of Autodesk Showcase to create stunning photorealistic renders of your final car assembly.

### Tutorial Work Flow:



## Getting Started with Autodesk Inventor

Autodesk Inventor is an application for creating 3D digital prototypes used in the design, visualization and simulation of products. As a Student or Educator you can obtain the Autodesk Inventor software at [www.autodesk.com/education](http://www.autodesk.com/education).

## Starting Autodesk Inventor

To review the Autodesk Inventor user interface, refer to the Beginner tutorial or click on the following link:

[Autodesk Inventor 2016 Tutorial User Interface](#)

## Datasets

All project files that are required for the tutorial are provided in a dataset.zip file. Download the dataset file and extract the files to your computer. Do not modify the file structure of the dataset files.

## Video Tutorials

Download the video tutorials supporting this tutorial. The video tutorials offer the same step-by-step software instruction for learners that prefer guidance through video format.

## F1 in Schools Rules and Technical Regulations

It is extremely important to that you design your car to comply with the current F1 in Schools rules and regulations. Each country has slightly different specifications that may change from year to year. It is critical that you download and review your country's F1 in Schools Rules and Regulations documentation and design your car to the outlined specifications. Activities in this tutorial leverage F1 in Schools rules and regulations for 2015-2016 and may not apply to your country.

**Important:** Confirm the F1 in Schools rules and regulations for your country and competition before getting started. Go to your local F1 website and download the F1 in Schools rules and regulations documentation <http://www.f1inschools.com/international-sites/>.

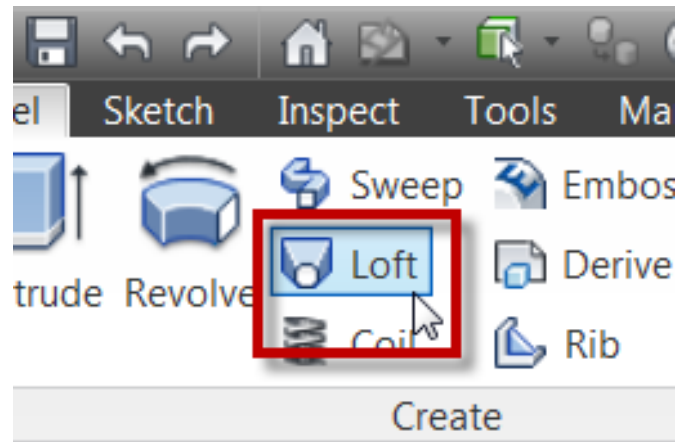
## Tip Set 1: Alternative Approaches to Modeling the Car Body

In this section, you will review alternative methods of modeling an F1 in Schools car in Autodesk Inventor. For video instructional support, download the step-by-step video tutorials for this activity.

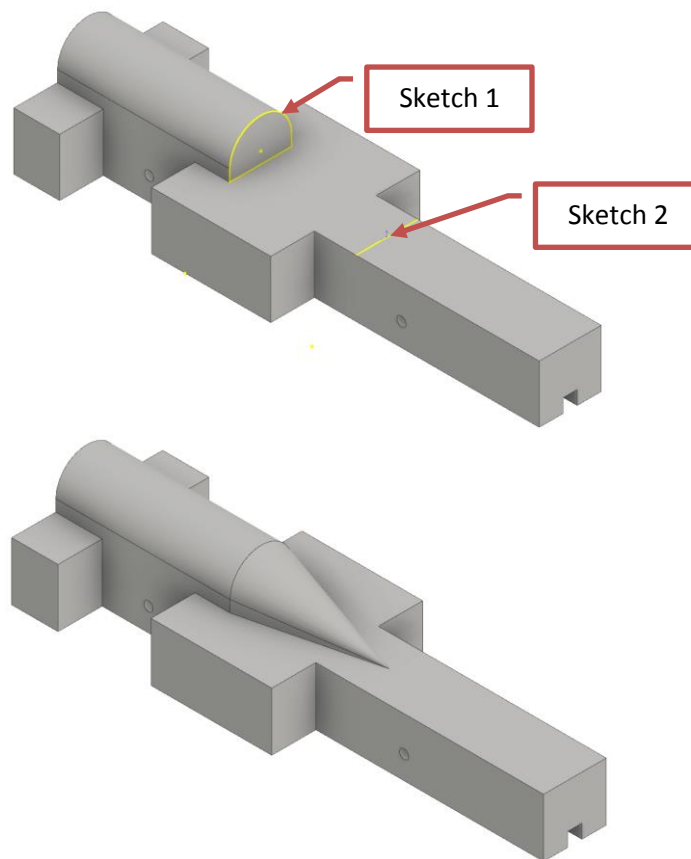
## Tip 1: Creating Lofted Features

Lofts blend multiple profiles, called sections, and transition them into smooth shapes. In this section, three examples of creating lofted features are shown.

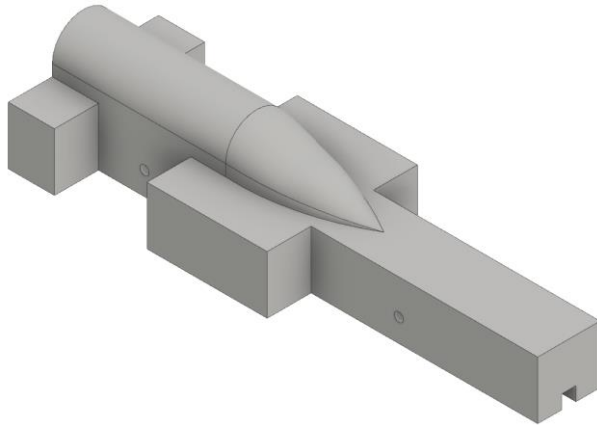
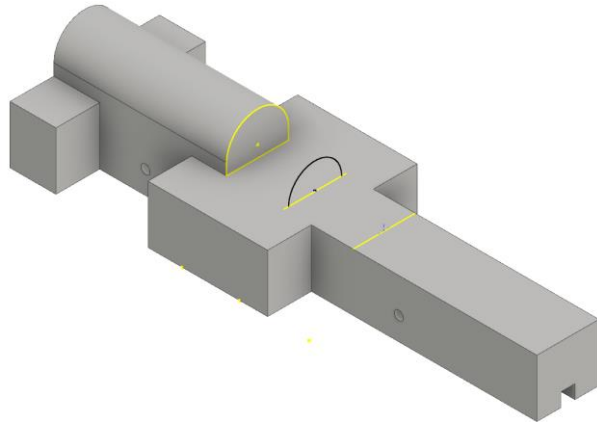
1. The Loft tool is located on the Create panel.



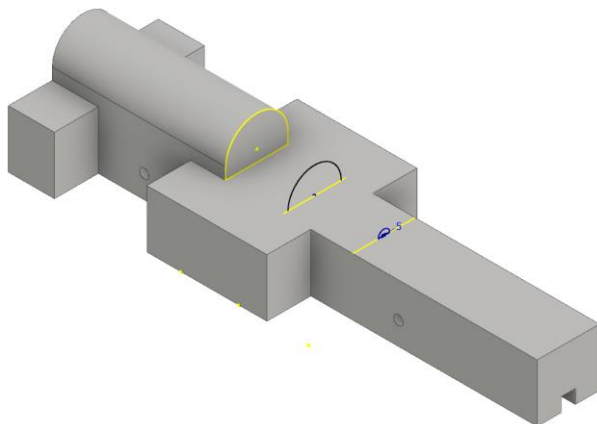
2. Select the sections you want to blend. In this example, two sketches are used, one of which is a point.

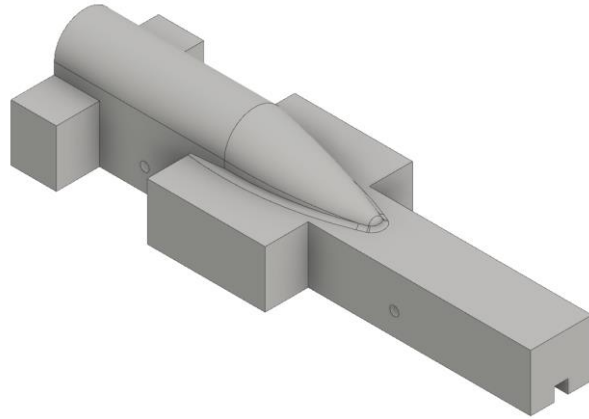


3. In this example, three sketches are used, the same two as the previous example plus another sketch to modify the shape.



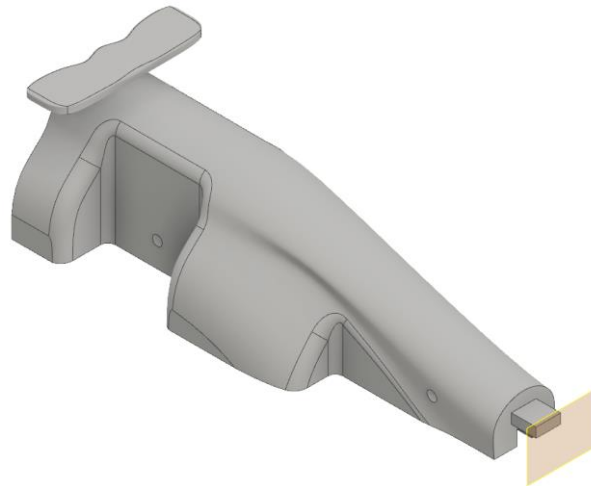
4. In this example, three sketches are used. The point is replaced with a profile.



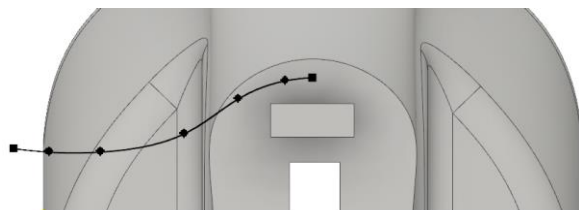


### Tip 2: Creating alternative wing structures

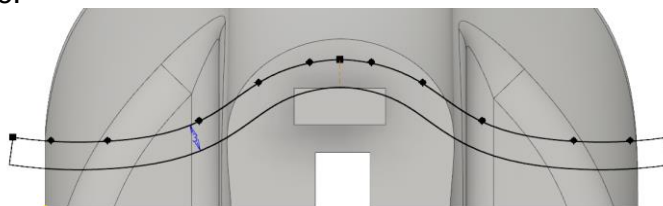
1. Create an offset work plane on the nose of the body then start a new 2D sketch.



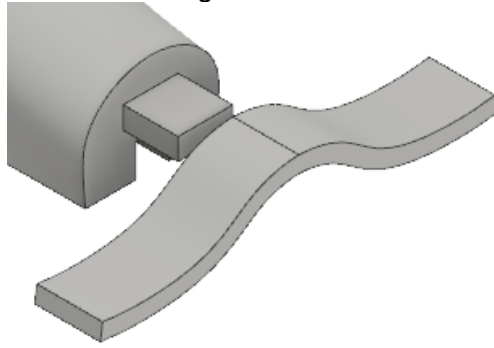
2. Sketch the profile of your wing using a spline. Refer to rules T10.1 – T10.12 to ensure the design is compliant.



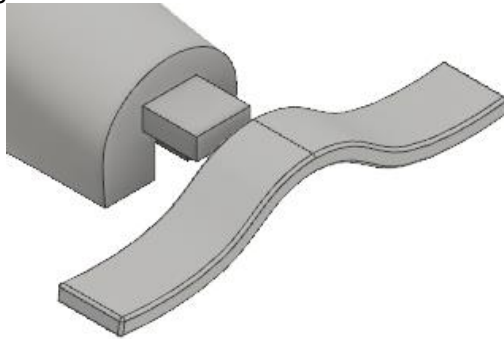
3. Mirror the spline offset to create the lower half. Two short lines need to be added to close the profile.



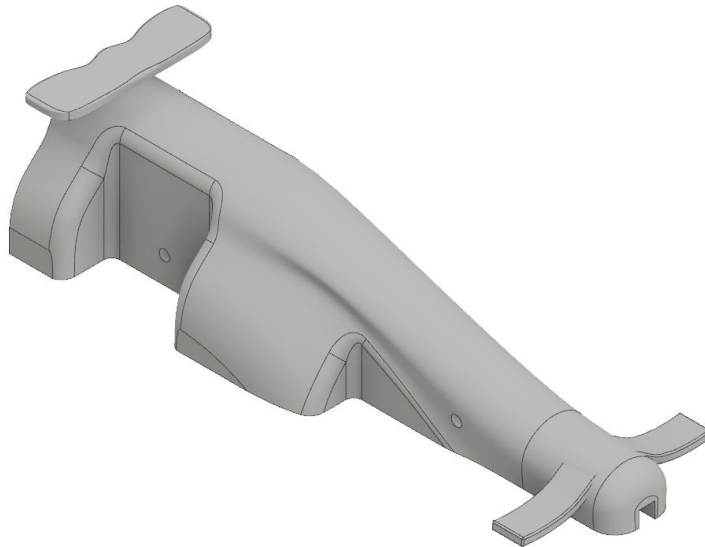
4. Extrude the profile to create the wing.



5. Add fillets to the edges.



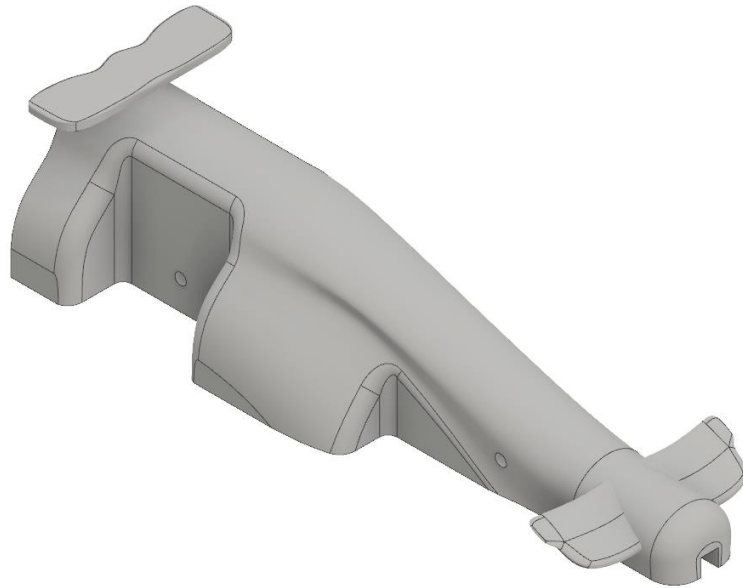
6. Make all parts of the assembly visible.



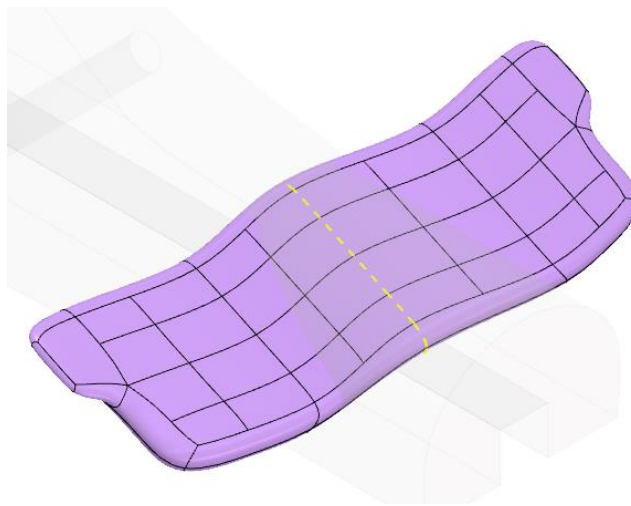
**Note:** The nose cone and extruded wing can be 3D Printed and tested. Modifications to the wing can be done by modifying the spline sketch or the size of the extrusion.



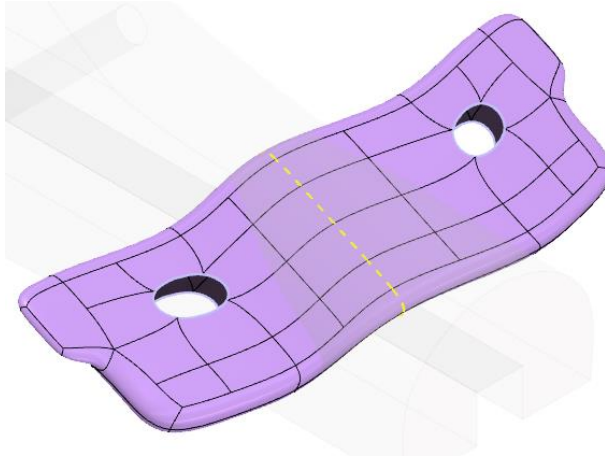
7. Wings created using freeform techniques can be easily modified. The front wing shown below was created using a freeform box.



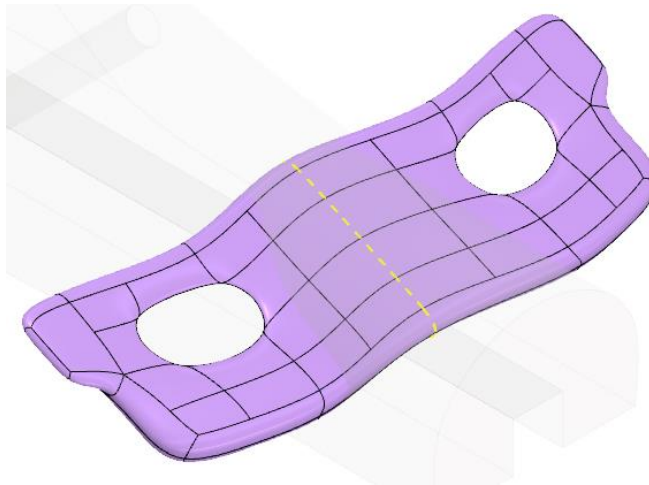
8. Use Edit Freeform to subdivide the selected faces on the top and bottom sides of the wing.



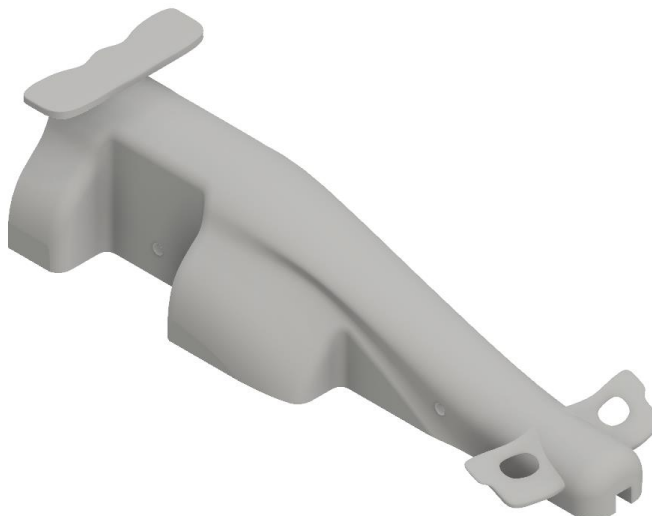
9. Delete faces on the top and bottom. Note that the sides of the holes are open.



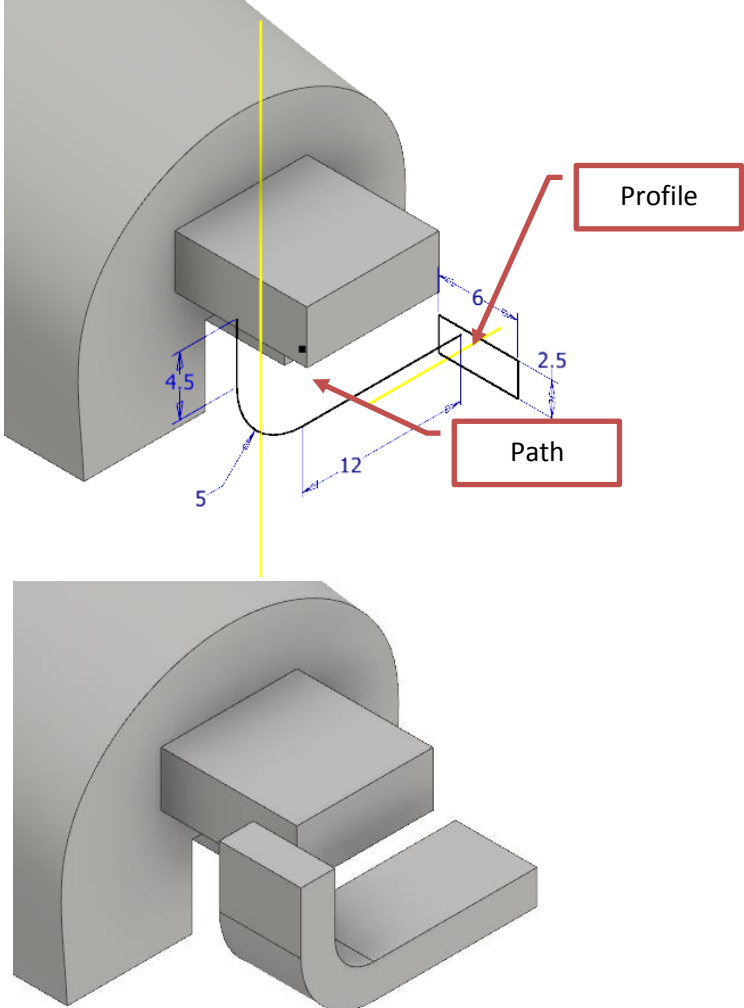
10. Use Merge Faces to close the freeform shape.



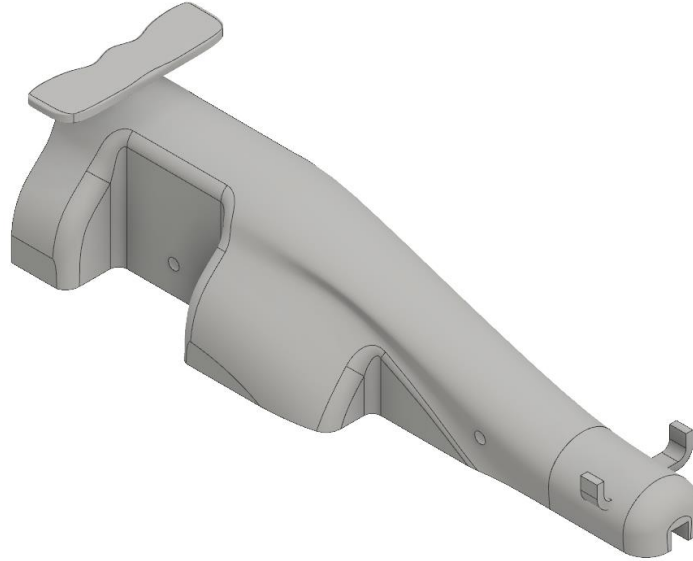
11. Return to the main assembly.



12. The front wing can be supported in different ways. By creating a profile sketch and sweep path as shown, the Sweep tool is used to create one half of the support.



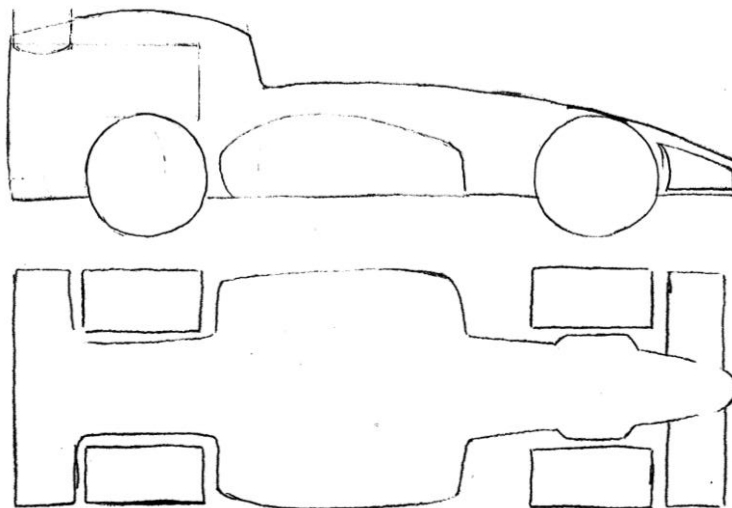
13. Mirror the sweep feature to complete the support, then make all parts of the assembly visible. It is ready to support a range of front wing designs.



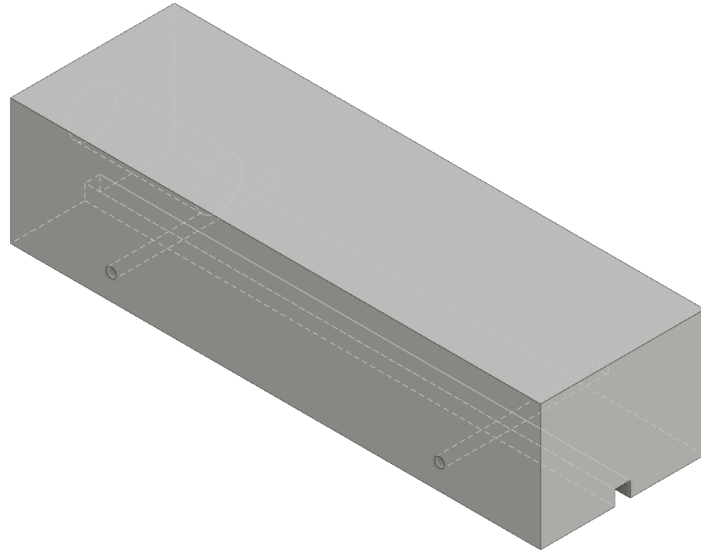
### Tip Set 2: Using a hand sketch as an image

In this section, you import a hand sketch as an image. This is an alternative approach to designing the F1 in Schools Car body. Most good designs start off with a simple pencil sketch, and this is still an effective and quick way to generate ideas. For video instructional support, download the step-by-step video tutorials for this activity.

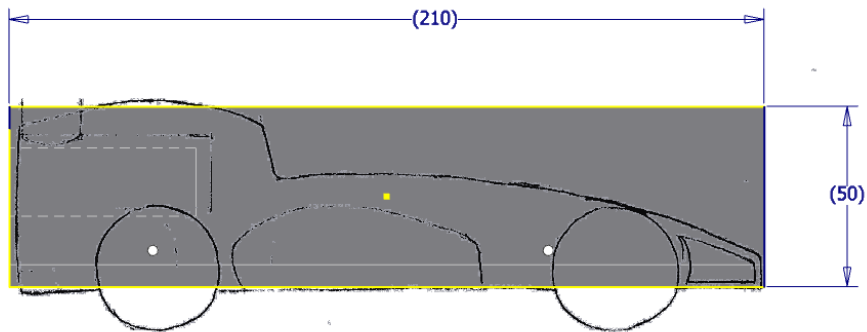
Start by creating sketches of your F1 car design concept on an A4 sheet: a front view and plan are shown. The outline of the sketch should be the same dimensions of the car block: **210mm x 65mm x 50mm**.



1. In Autodesk Inventor, open an F1 model block.



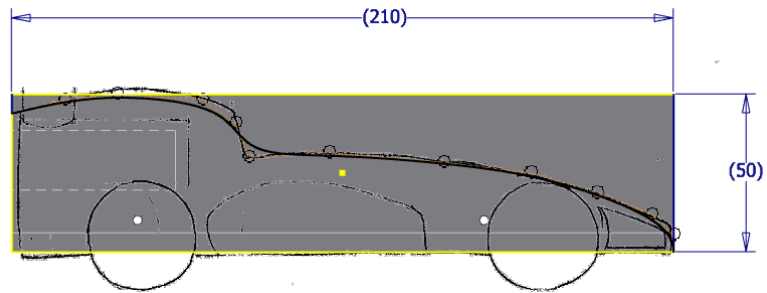
2. Start a new 2D sketch on the front face of the block.
3. Use Insert panel > Image to open the front view sketch of your design, then place it on the front face of the block. Resize the image to match the block dimensions.



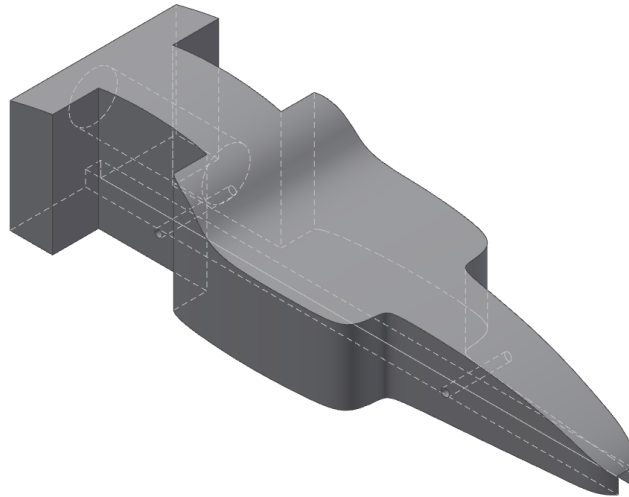
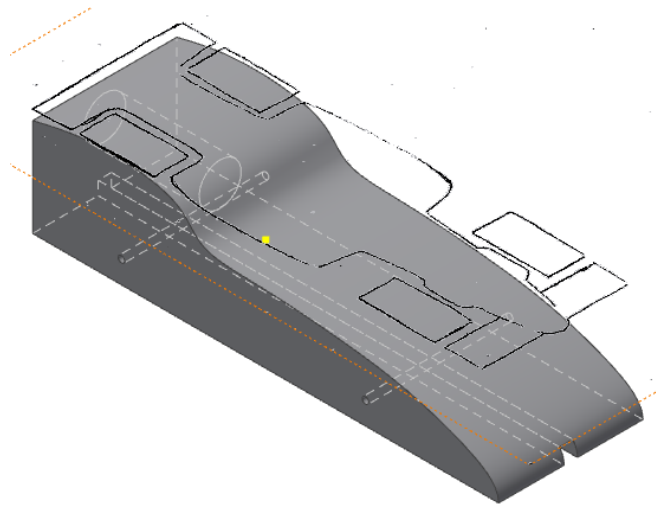
5. Repeat this workflow for the other views.

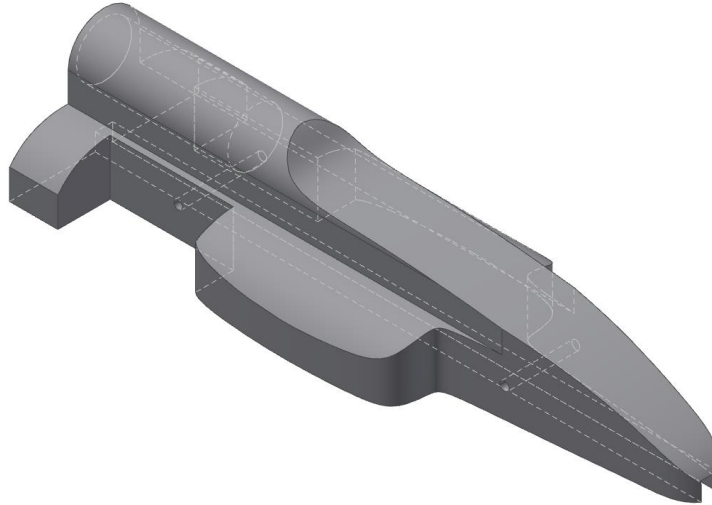


6. In each sketch, trace over the image using a line or a spline.



7. Extrude the three sketches to model the basic shape of the car design.



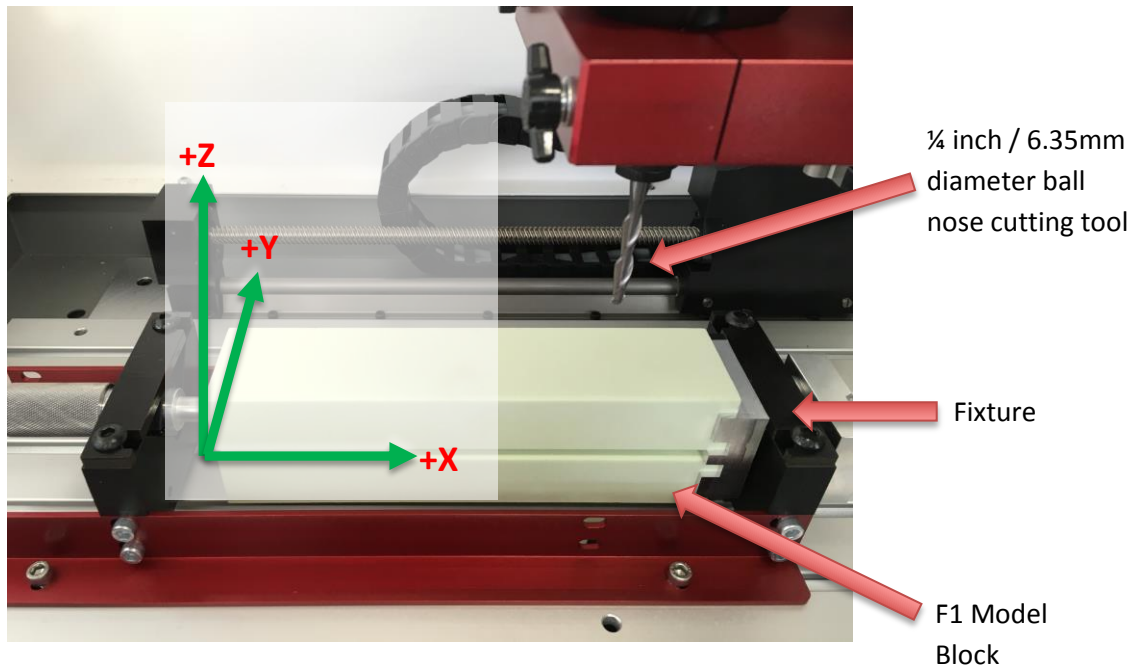


## Design for Manufacturing

It is very important to have a basic understanding of how the car body will be manufactured in order to create a successful design. In industry, all products are designed with consideration given to any limitations that may exist due to the available or chosen manufacturing methods. An F1 in Schools car is no different. It is important to understand the manufacturing technology and process requirements so that the car designer can create a car body shape that is actually possible to manufacture by a CNC machining process.

CNC (Computer Numeric Control) machining is a very important and widely used manufacturing method in industry. This is why it is compulsory for F1 in Schools teams to manufacture their car bodies using a CNC machine. Many schools are equipped with 3 axis CNC machines which is the minimum requirement for car body manufacture. High speed 3 Axis CNC Routers are ideal for making F1 in Schools car bodies. Autodesk F1 in Schools tutorials support manufacturing via a Denford 3 Axis CNC Router.

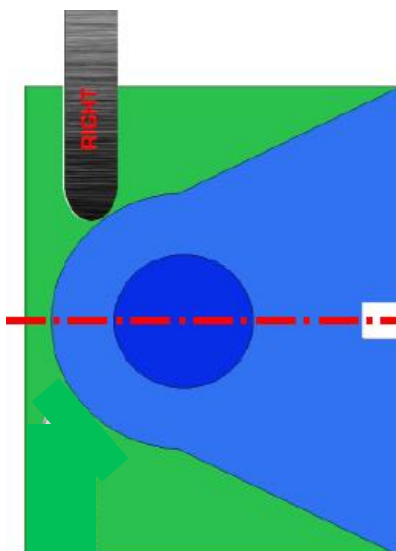
The recommended standard CNC machining method is to machine car bodies using two machining operations, one operation from the left side of the car and one from the right side. For each operation the F1 Model Block is mounted on its side in the CNC machine via clamping in the special F1 in Schools Machining Fixture. This method provides for a wide range of car profile designs to be machined with a minimum amount of machining operations. The picture below illustrates this.



The green arrows above indicate the 3 axis direction system of the CNC machine. These are the 3 axis of direction that cutting tool moves in, often simultaneously, in order to remove the excess Model Block material revealing the profile of your F1 in Schools racer.

The standard method of manufacture is to machine the car body using two machining operations, one machining operation on each side of the car. The right side of the car is machined with the Model Block mounted as pictured above, the Model Block is then rotated 180 degrees about the x axis to machine the left side of the car body. The left side machining operation is simply a mirror image of the right side.

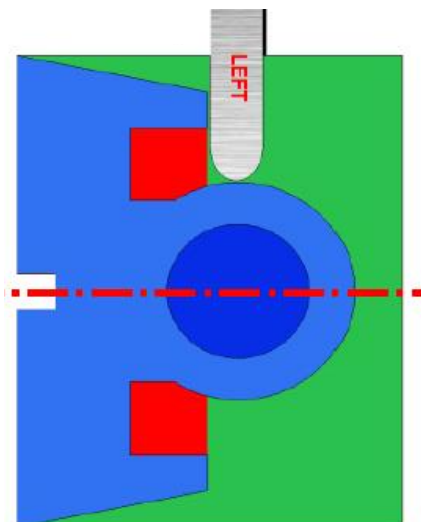
Due to there being only 3 axes, or directions of movement that the cutting tool can move in, some shapes or profiles may not be possible to machine. The diagrams below help explain this further.



The Model Block (green) and car profile (blue) are shown oriented on their side in the CNC machine. The dark blue circle is the CO2 canister hole in the Model Block.

The cutting tool (shown in grey) can remove all of the material to produce the design (shown in blue) as it can be reached from left and right sides of the car.

The material shaded in red cannot be removed as the tool cannot reach this area from the left and right sides.



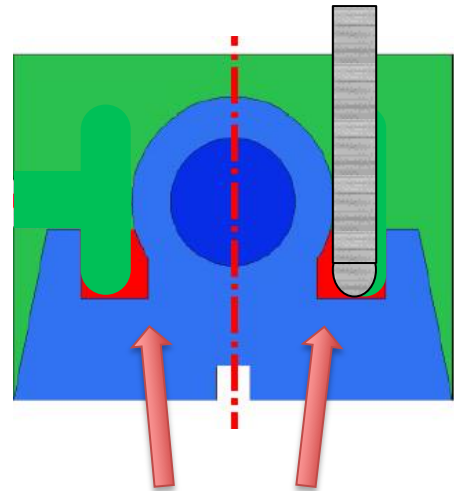


As pictured on the right, it is possible to mount the Model Block in the CNC Router oriented to allow for machining from the car body top. This can then also be inverted to allow for machining of the car body bottom if required. These would be additional machining processes increasing complexity, time and cost to machine the design. Note that with this design, there are still areas shown in red that the cutter cannot access, these areas are not possible to machine using any orientation.

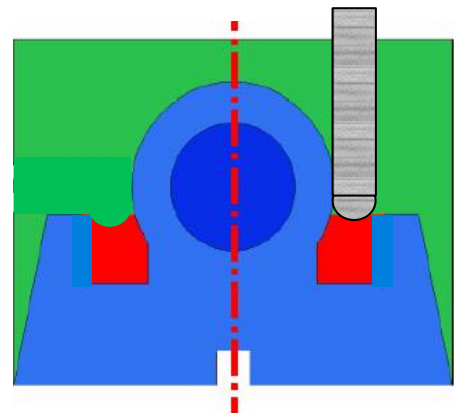
Finally, the size and shape of the cutting tool needs to be considered. The standard machining process for F1 in Schools car bodies uses a ¼ inch (6.35mm) diameter ball nose shaped cutter. Looking at the diagram above, you will notice that a small radius / fillet of material (in red) remains where two edges meet at an internal sharp corner. This is due to the ball nose shape of the cutter tip.

The example to the right is a similar body profile to the above example, however, here the slot down next to the left and right sides of the CO2 canister housing is not as wide. The slot is narrower than ¼ inch / 6.35mm and therefore the cutter cannot access and remove the material in red. Any slot or groove features like this that are narrower than the diameter of the cutter cannot be machined.

Hopefully now you have a better understanding of the CNC machining process used to manufacture F1 in Schools car bodies and the few limitations that this imposes. You should now keep these factors in mind as you unleash your creativity in designing your F1 in Schools racecar bodies.



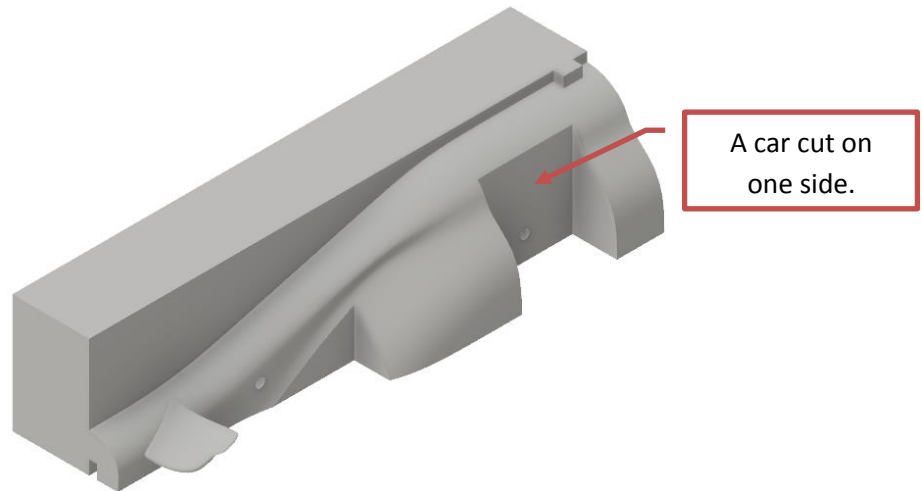
ABOVE: Material remains in the sharp internal corners (shown in red) due to the ball nose shape of the cutter tip (shown in grey). Model Block material that will be machined away is indicated in green



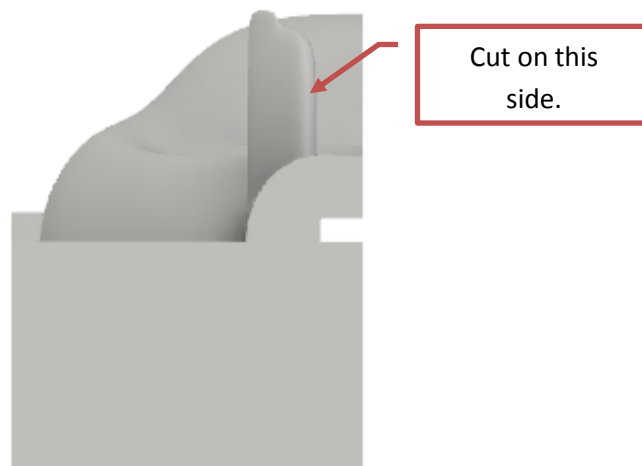
### Tip Set 3: Machining from 4-Axes.

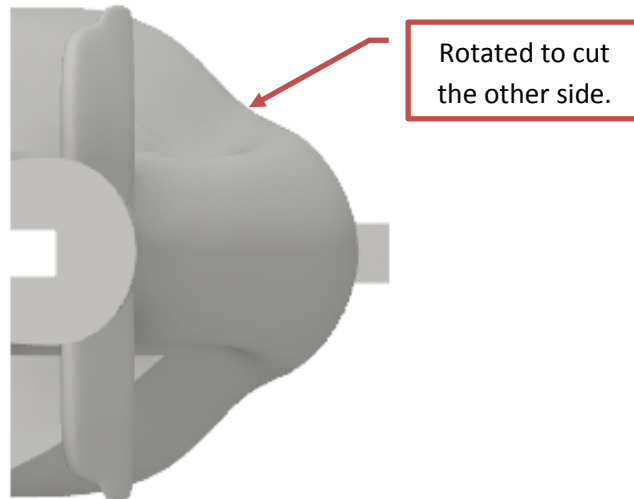
In this section, you review what is possible if you machine your car from four axes instead of the usual two or three. For video instructional support, download the step-by-step video tutorials for this activity.

1. With standard 2-axis machining, the car is cut from the F1 in Schools Foam Block on two sides.



2. The block is cut on one side, then rotated to cut the other side.





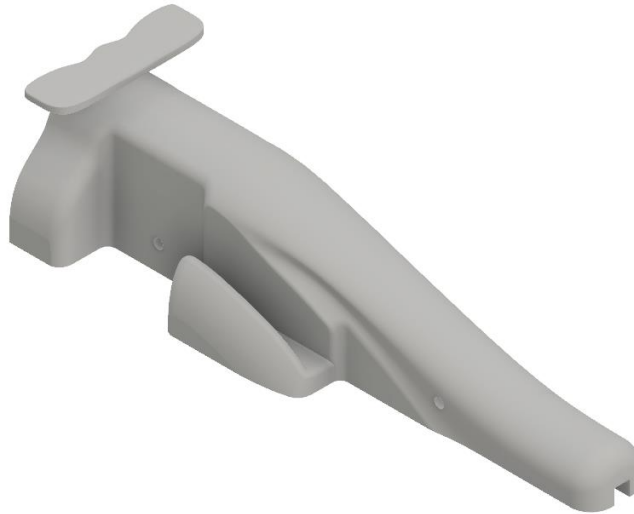
3. It is possible to cut the car from above and underneath by rotating the block at 90° intervals.

Tools cut in this direction.  
Rotate the block to cut in both directions

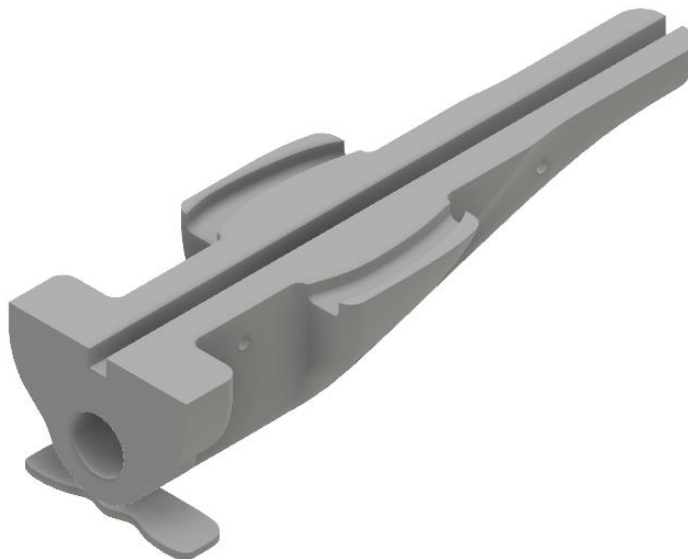


4. This opens up more possibilities with the design of your car as it allows cuts directly into the face of the body. These are not visible from the side.

5. The side pods can be modified to allow for better air flow and still be machined as shown above.

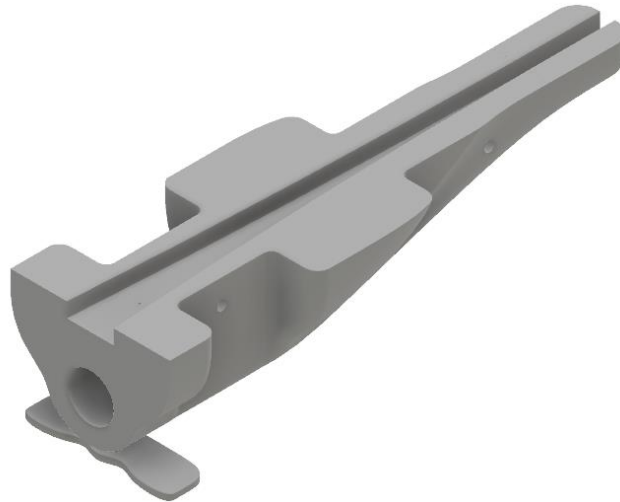


The underside of the pods can also be modified.





6. Modifying the tether line slot also assists in channeling the air under the car.



### Tip Set 4: Modeling Your Own Wheel Designs

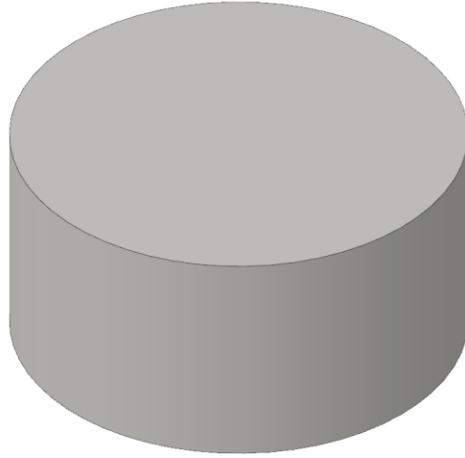
In this section, you will be shown some tips regarding designing your own wheels. For video instructional support, download the step-by-step video tutorials for this activity.

#### Tip 1: Model a Basic Wheel

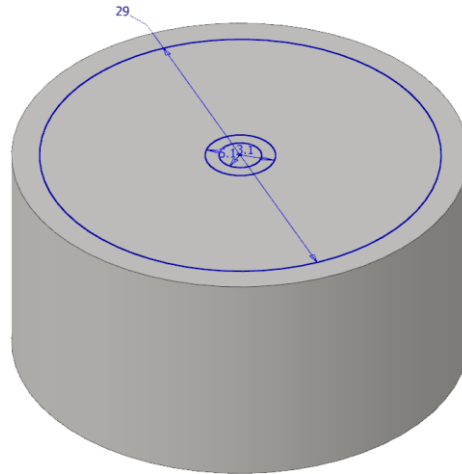
Before you start the wheel design, consider the following;  
What method will you use to help them spin: Bearings? What size bearings? How will these fit in the wheel?

Secondly, you need to consider what material and manufacturing method you will use. This will determine features like the wall thickness. Refer to rules T8.1-8.10 regarding wheels.

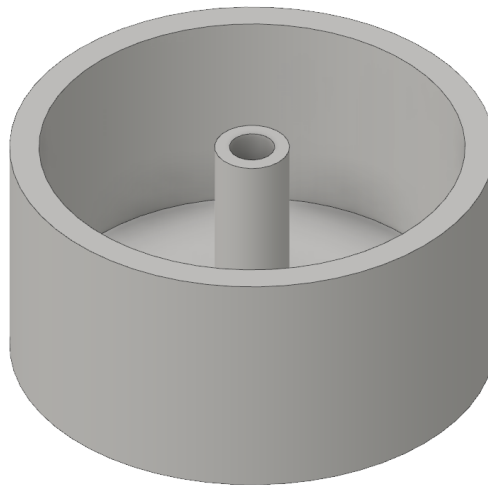
1. Start a new part file and create a cylinder based on your design specifications.



2. Sketch concentric circles on one face.

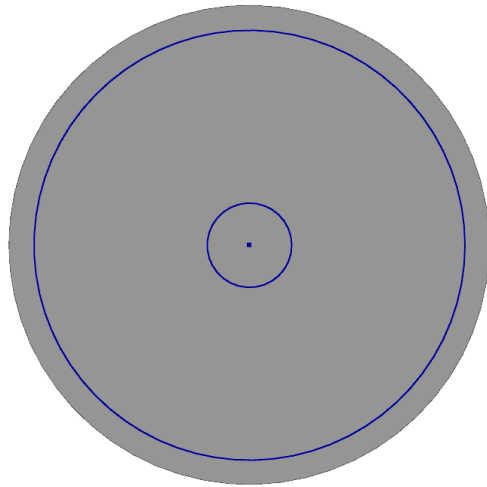


3. Extrude the circles as shown.

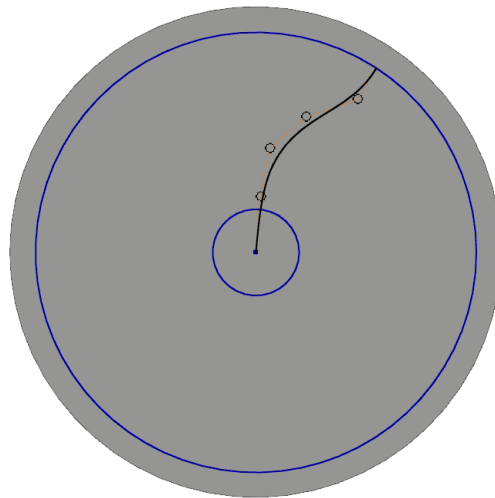


## Tip 2: Adding Spokes

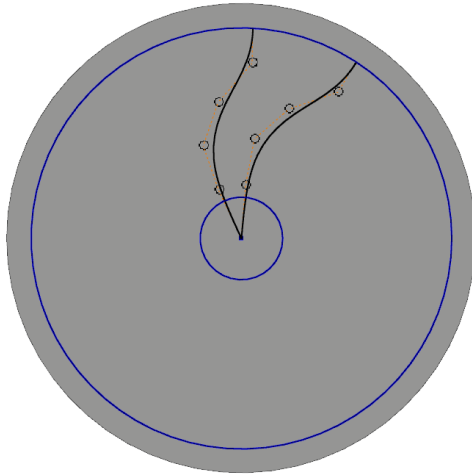
1. Start creating the spokes by sketching circles on the front face of the wheel. These should match the wall thickness and center hub of the wheel.



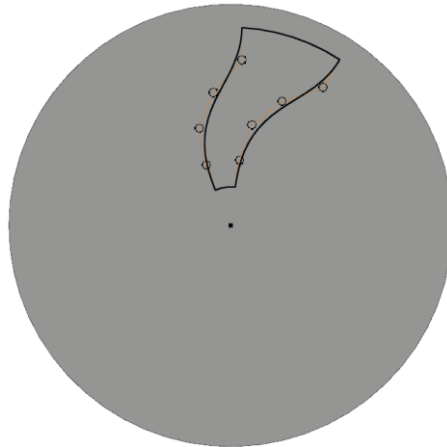
2. On the same face, sketch a line from the center of the circle to the outside. Use a spline to create more interesting shapes.



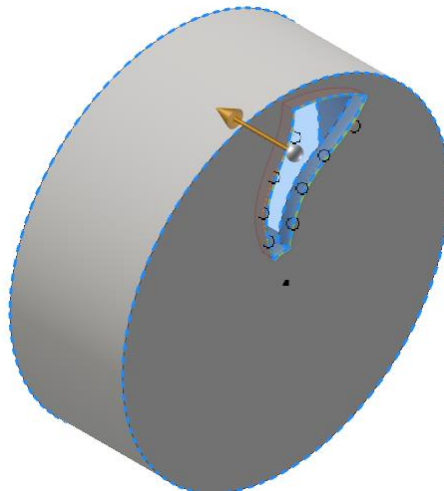
3. Create a second spline using Rotate / Copy. In this design the angle is 30 degrees.



4. Trim the sketch to leave just the sketch of the profile as shown.

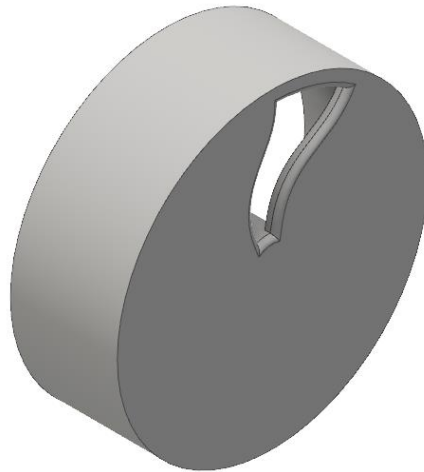


5. Extrude the profile through the thickness of the wall.

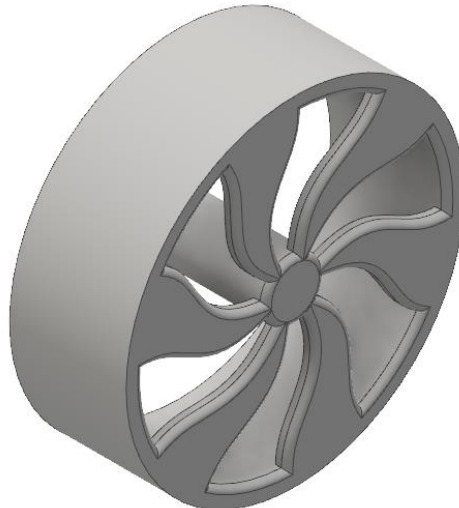




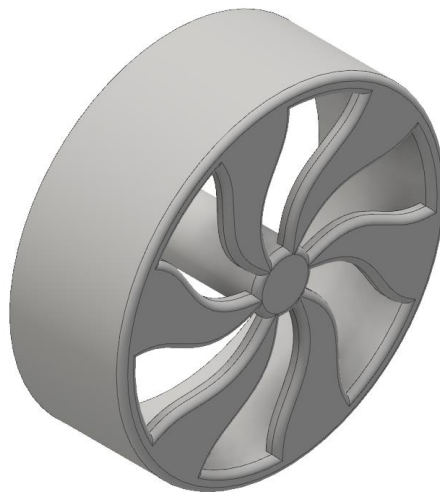
6. Add fillets to the edges of the opening.



7. Create a circular pattern of the extruded feature and fillets. In this example there are 6 features.

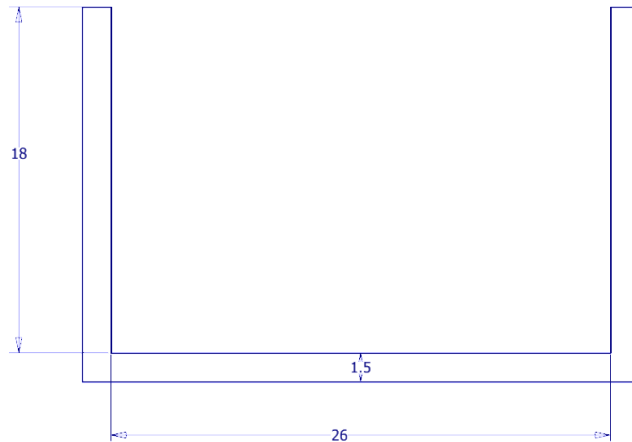


8. Add fillets to the outside edge of the wheel.

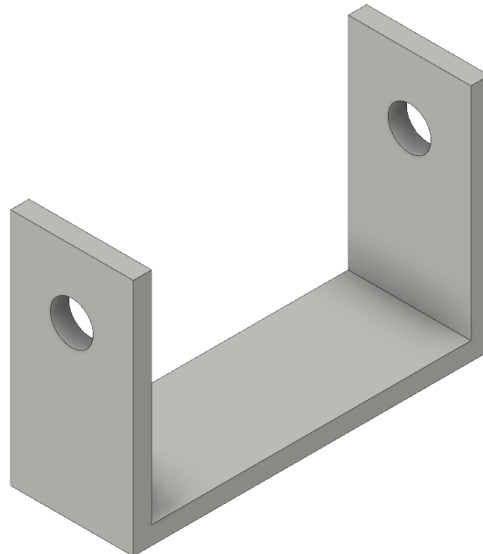


### Tip 3: Designing Wheel Housings

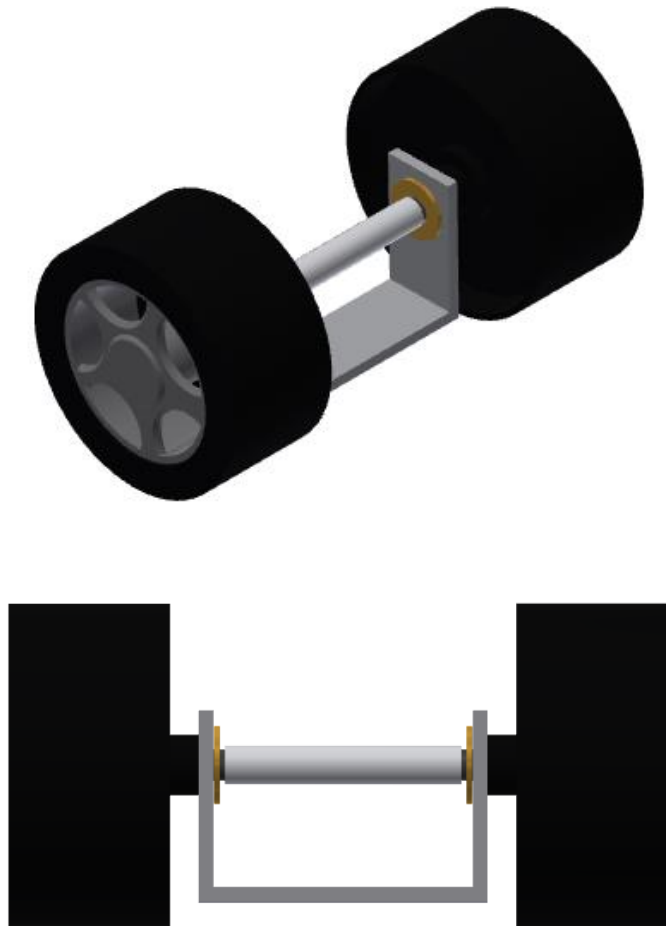
Wheel housings allow an alternative method of securing the wheels to the body. Download the step by step video instructions for this activity. Create a sketch, then offset the sketch as shown. The dimensions of the sketch are based on the distance between the washers on the front and rear axle. The depth of the housing must clear the bottom of the car body and be clear of the ground.



1. Extrude the sketch, then add holes for the wheels.



2. In the car assembly, add the wheel housing.



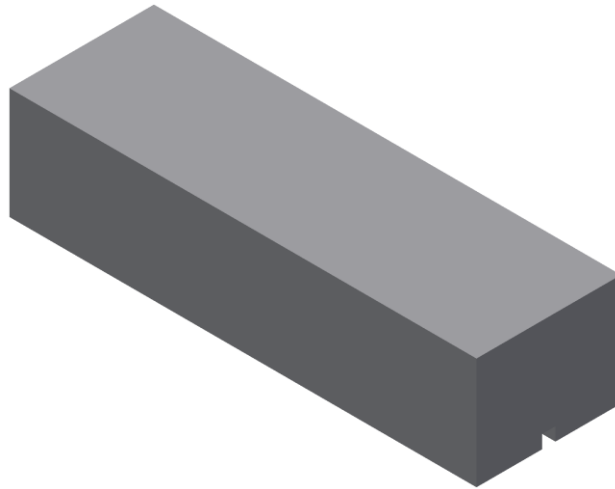
### Tip Set 5: Analyzing the Mass of a Model

In this section, you calculate the weight of your car model. Rule T3.5 states the total weight of the car excluding the CO2 gas cylinder should be a minimum of 55 grams.

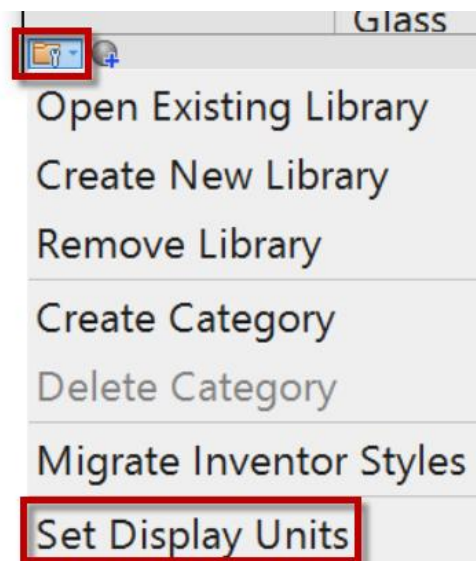
#### Tip 1: Apply the Material to the Block

Using the F1 in Schools block first, set the material density so that your Model Block is the standard weight of 112g.

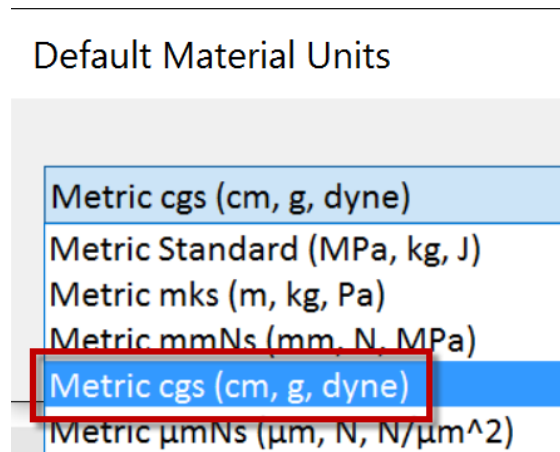
1. Open your F1 in Schools Model Block.



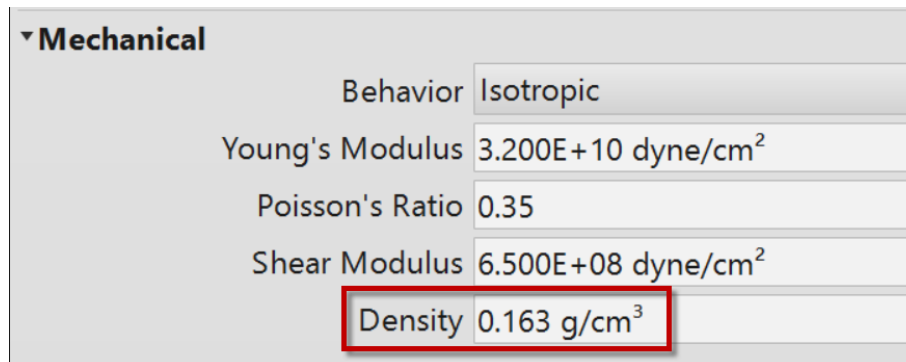
2. On the Tools tab > Material and Appearance panel, click Material.
3. At the bottom left of the dialog box, click the down arrow beside the folder icon, and then select Set Display Units.



- From the list, select Metric cgs, then click OK.

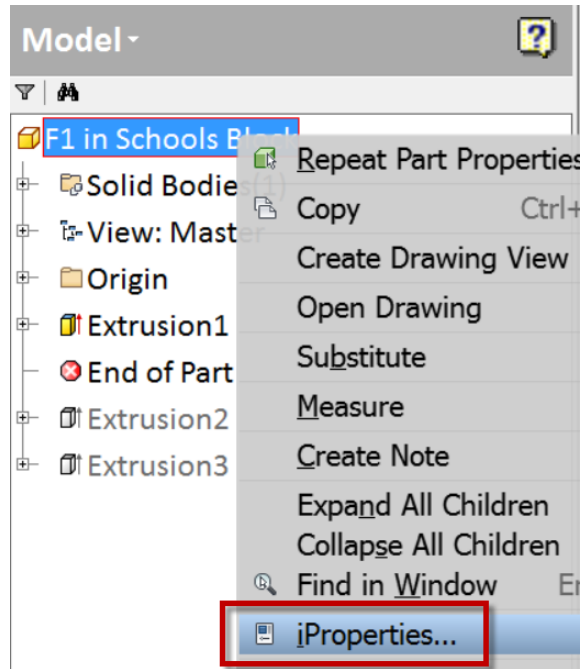


- In the Material browser, double-click Polystyrene. The Inventor materials list does not list polyurethane foam, so you will use polystyrene, then edit the density to match the F1 block.
- In the Material Editor dialog box, click the Physical tab, then expand Mechanical.
- For Density, edit the value to **0.163**.



- Click OK, then close the Material Browser.
- On the Quick Access Toolbar, select Material.
- From the list, select Polystyrene. The modified density is applied to the block.

11. In the browser, right click the part name, then click iProperties.



12. On the Physical tab, click Update. The Mass of the block with the tether line slot and cartridge chamber is 0.108 kg or 108 grams.

13. Use this same workflow to determine the mass of the F1 car you have designed.

## Tip 2: Calculating the Mass of Other Car Parts

1. To determine the mass of the other car parts (for example 3D printed wings) use the same workflow. For example, ABS filament commonly used in 3D printers weighs 1060kg/m<sup>3</sup>
2. The wing design is unlikely to be completely solid when printed, so it may be significantly lighter than calculated. Measurements need to be carried out on the physical items also.
3. To determine the total mass of your car design, include the axles, tether line guides and wheels.

## Next Steps

Now that you have read through the advanced tutorial, it is time to practice and experiment further with Autodesk Inventor to see what it is capable of. Familiarize yourself further with the Technical Regulations and design your own world-conquering F1 in Schools Car. Good Luck!

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