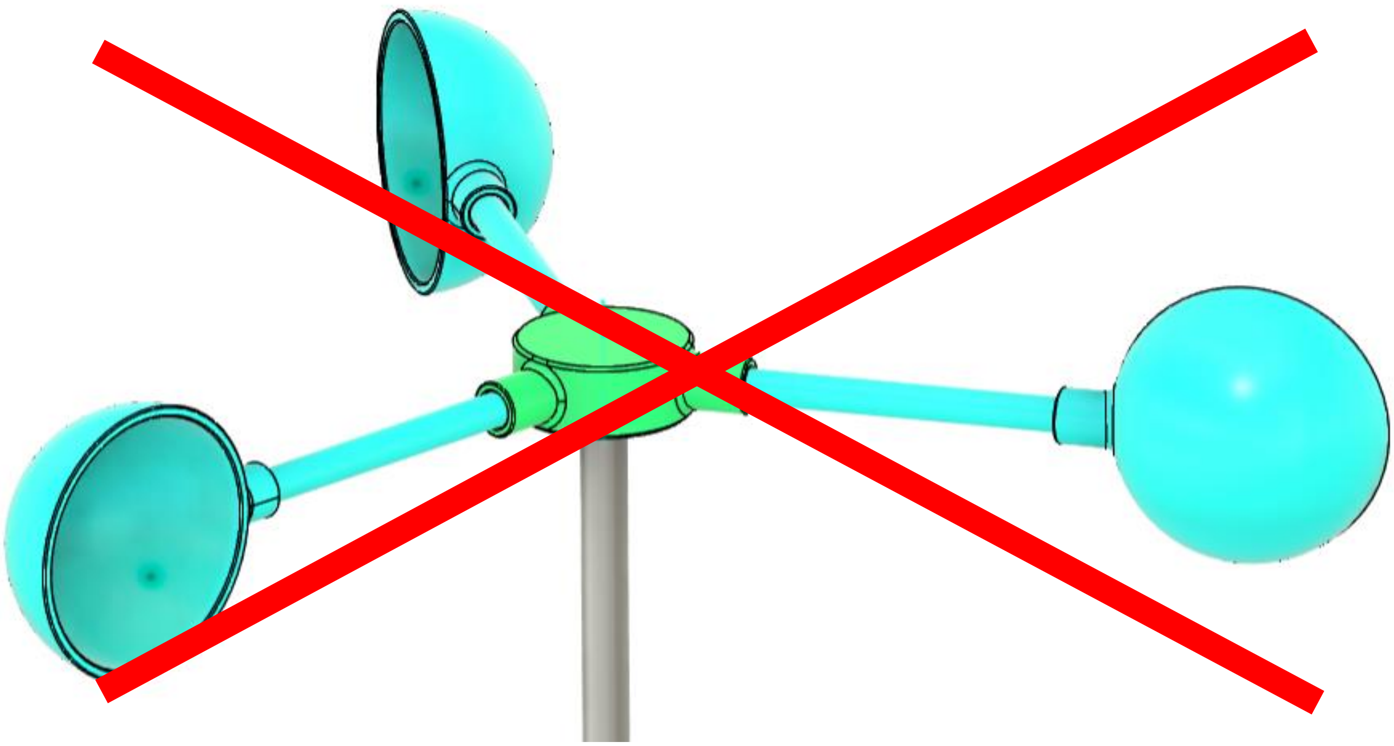
Mr. Barbetta’s ***“I don’t care about 3D Printing. I just want the art credit.”*** class

Anemometer Redesign

Out, damned supports! Out, I say!



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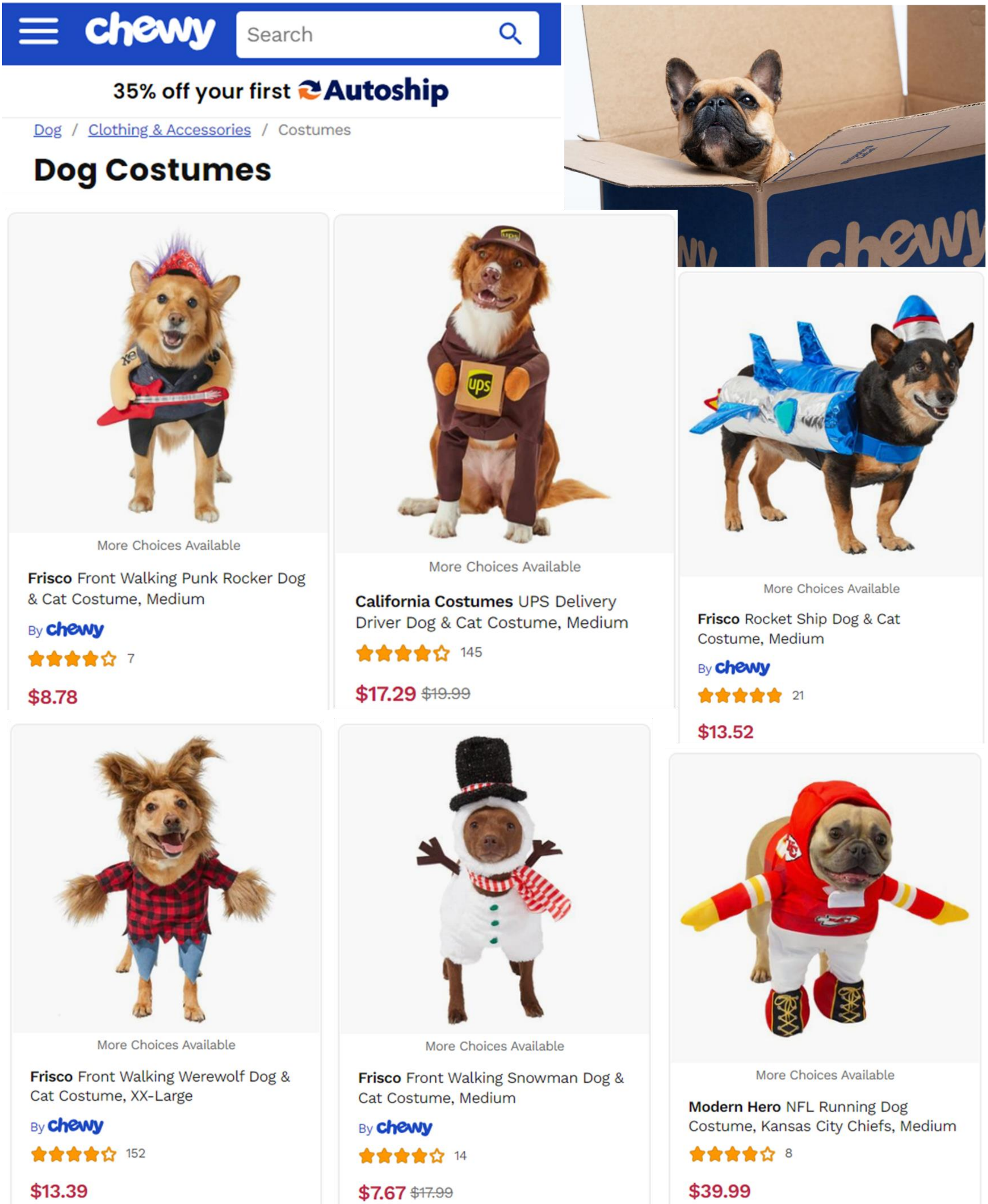


Contents

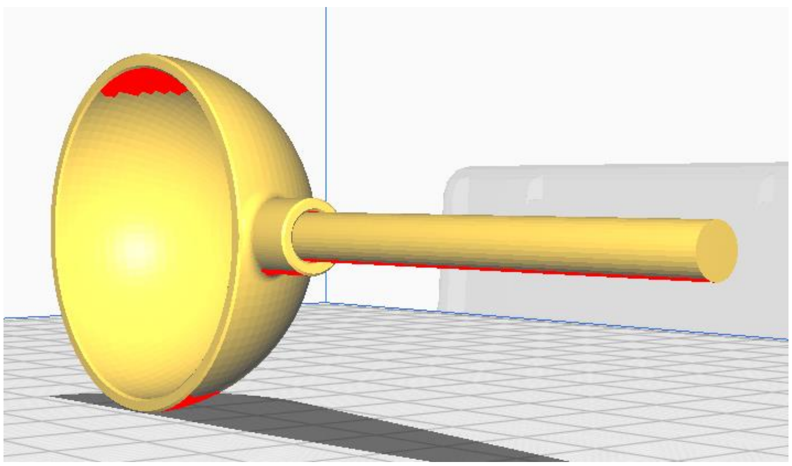
What’s the problem?

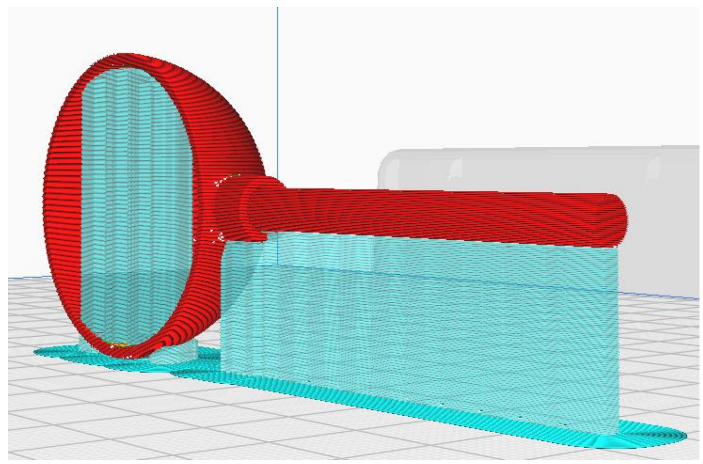
Poor DFM (Design for Manufacturing) is the problem.

Of course for production (high quantities) injection molding would be used and the issue of supports would not be relevant. However, if one wishes to use 3D printing for a *low production run*, it makes sense to optimize the process. One way to implement good DFM is to create a design that doesn’t need supports.

Supports relate to extra support material to print elements of the part that are not on the build plate. One cannot print over air. There must be lower layers. Every slicer program, such as Ultimaker Cura, can generate these supports. The downsides of doing so include a longer print time, the use of more material, additional labor, and resulting rough surfaces where the support material connects to the part. Sometimes it is required for these rough surfaces to be sanded or scraped to remove remnants of the supports and to reduce roughness.

Below is an example of an anemometer cup with extension imported into Cura. On the right side is the result of added support material, which Cura shows in blue. It should be noted that there are many options to creating supports. For example, an alternate support option is the use of *tree supports*.



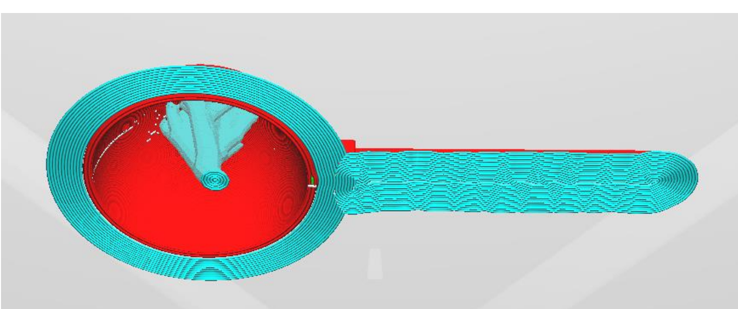


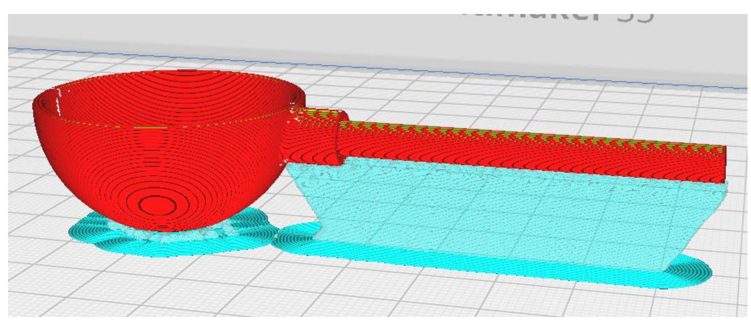
Below are the results of repositioning the cup.

On the left side the part has been rotated with the open end of the cup down on the build plate.   The view was be rotated in Cura to view the underside. Supports are needed inside of the cup and under the extension.

One the right side in another position of the cup with the necessary supports.

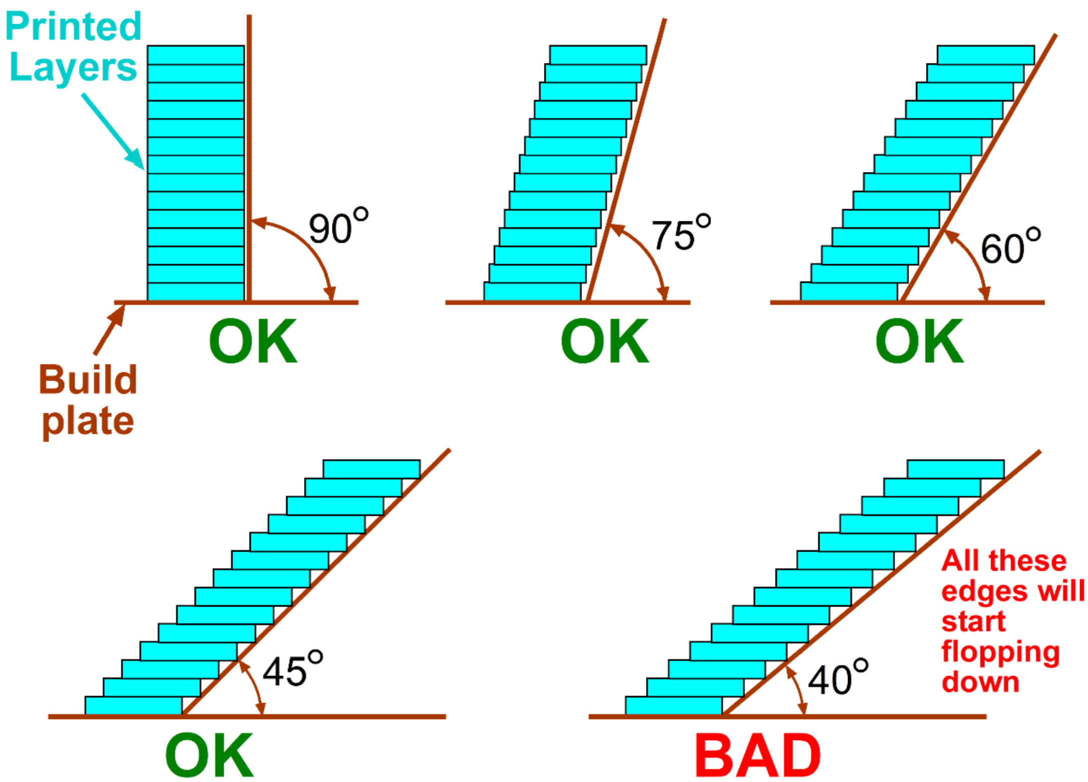
We want a new design!

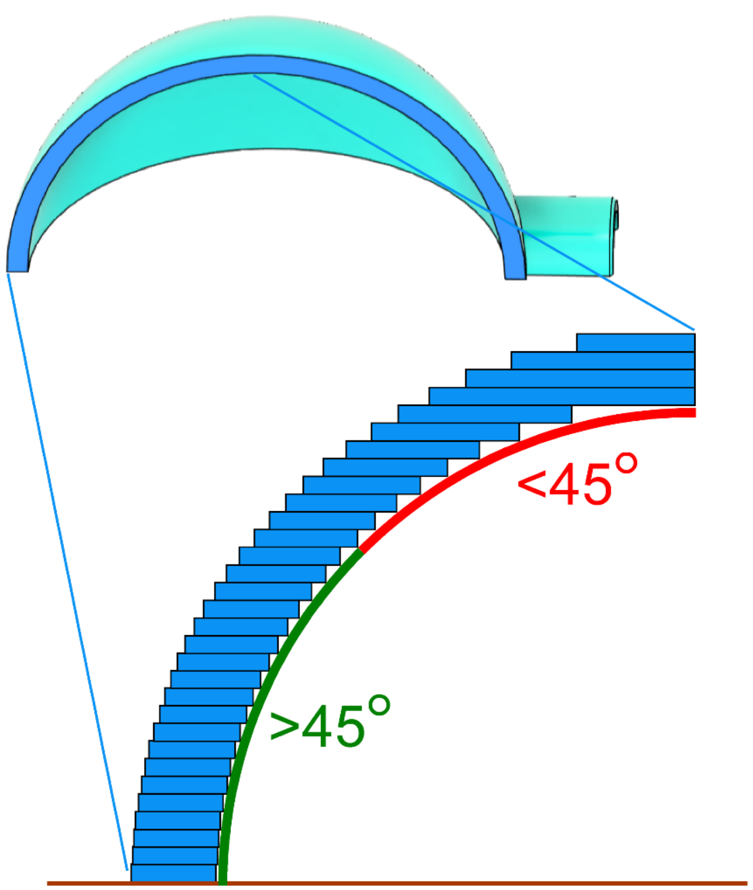




45 Degree Rule

A 3D Printer starts printing the 1st layer on the **build plate** and then prints layer upon layer. An overhang is any printing that is not over a lower layer and thus "overhangs". Overhangs can be printed as long as the surface they form is at an **angle >= 90 degrees**. Note that these illustrations can be considered as magnified view of a small section of the 3D printed object. **Each layer may only be 0.1 mm thick**.





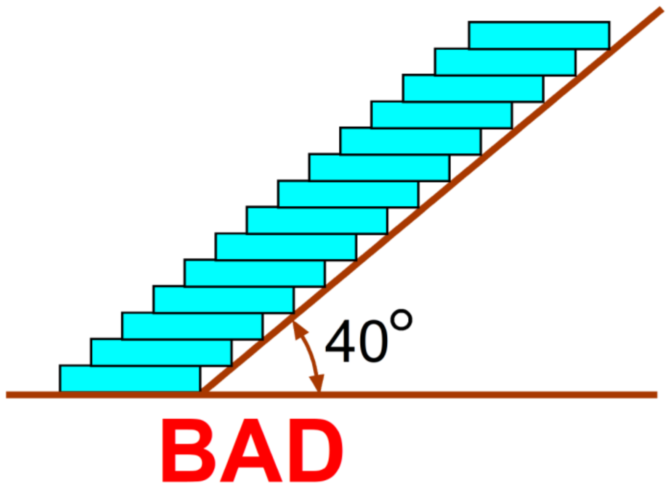
The illustration below shows part of the cup cross section with exaggerated layer thicknesses.

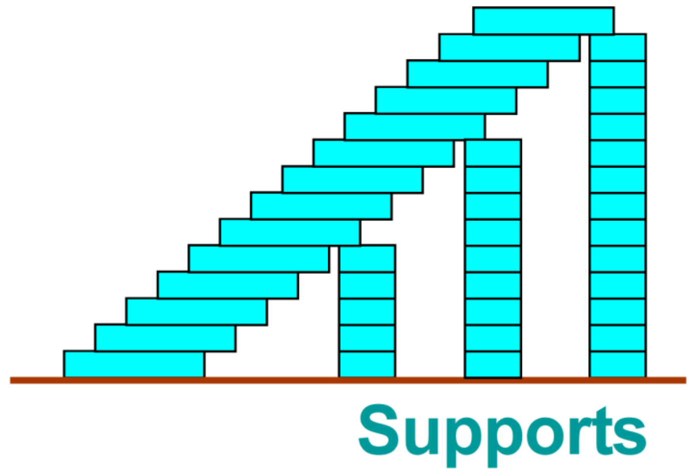
The lower portion of the inner wall has angles that are greater than 45 degrees, which can be 3D printed.

The upper portion, called out with a red line, has angles that are less than 45 degrees. This upper wall section will start flopping down causing the top of the cup to collapse.

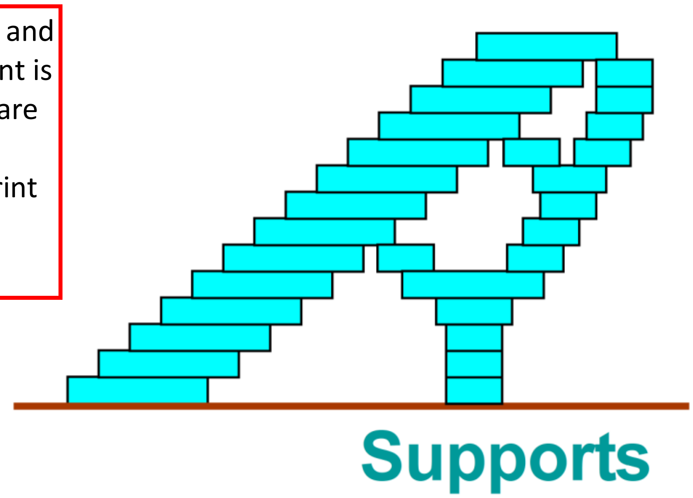
3D Printed Supports

The **slicer** software, which converts the STL file(s) to the printer format, can **automatically generate supports** to allow the printing of overhangs that violate the 45 degree rule. Slicer software, such as Cura, often has many **settings to configure the support generation**. There can also be a setting for the type of supports. Shown here is an illustration of simple vertical and tree supports.

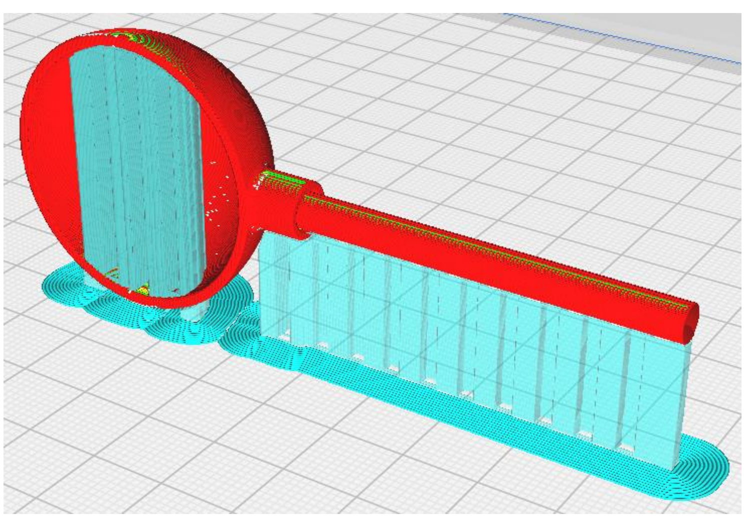




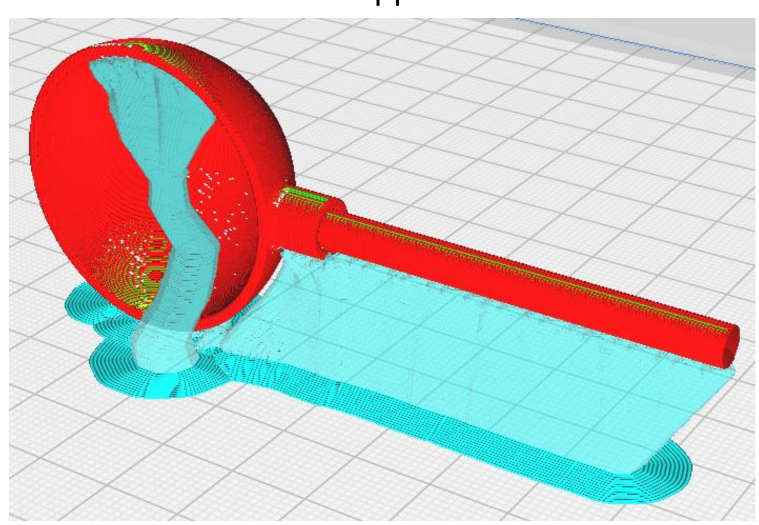
Supports are typically printed with the same material and at the same time as the printed object. When the print is finished and removed from the printer, the supports are then broken or cut away.
Alternatively, a 3D printer with a dual extruder can print the supports with a different material that can be dissolved away with a second process.



Normal supports



Tree supports



Some Hints

1) the cups do not have to be round

2) the extension rod does not have to be in the center of the cup (or other shape that “catches” the wind)

3) the extension rod can be a separate part

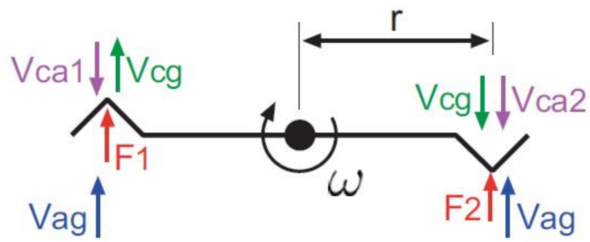
Deliverables

Your initials should be added to the design. Note that the Cookie Cutter document has instructions for adding text to either a flat or curved surface. The Ringy-Thingy document has instructions for adding text to a round surface.

A screenshot of the design in Fusion with your initials visible.

How Fast will it Spin ?

2 cup anemometer analysis - Joe Barbetta (jbarbett@stevens.edu)



Two cups are used to simplify the analysis and to avoid the need for drag coefficient data for shapes at various angles with respect to flow. Bearing friction is assumed to be 0.

Vca1,2 = velocity of cup with respect to air
Vcg = velocity of cup with respect to ground
Vag = velocity of air with respect to ground
F1,F2 = force on cup

$$V_{ag} = V_{ca1} - V_{cg} \qquad V_{ag} = V_{cg} + V_{ca2}$$
$$V_{ca1} = V_{cg} + V_{ag} \qquad V_{ca2} = -V_{cg} + V_{ag}$$

$$F_D = \tfrac{1}{2}\rho v^2 DA$$ Force(drag) as function of fluid density, velocity, drag coefficient, area

$$F_1 = F_2$$ at equilibrium (no acceleration), no rotational friction

$$\tfrac{1}{2}\rho AD_{c1}(V_{ca1})^2 = \tfrac{1}{2}\rho AD_{c2}(V_{ca2})^2$$

$$D_{c1}(V_{ca1})^2 = D_{c2}(V_{ca2})^2$$

$$\frac{D_{c1}}{D_{c2}} = \left(\frac{V_{ca2}}{V_{ca1}}\right)^2$$

$$\sqrt{\frac{D_{c1}}{D_{c2}}} = \frac{V_{ca2}}{V_{ca2}} = \frac{-V_{cg}+V_{ag}}{V_{cg}+V_{ag}}$$

$$\sqrt{\frac{D_{c1}}{D_{c2}}}(V_{cg} + V_{ag}) = -V_{cg} + V_{ag}$$ now in terms of ground velocities

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$$D_R = \frac{D_{c1}}{D_{c2}} \qquad \sqrt{D_R} = \sqrt{\frac{D_{c1}}{D_{c2}}}$$ let's simplify equations by using ratio of draq coefficients

$$\sqrt{D_R}(V_{cg} + V_{ag}) = -V_{cg} + V_{ag}$$

$$\sqrt{D_R}V_{cg} + \sqrt{D_R}V_{ag} = -V_{cg} + V_{ag}$$

$$\sqrt{D_R}V_{cg} + V_{cg} = -\sqrt{D_R}V_{ag} + V_{ag}$$

$$V_{cg}(\sqrt{D_R} + 1) = V_{ag}(-\sqrt{D_R} + 1)$$

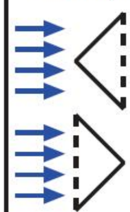
$$\frac{V_{cg}}{V_{ag}} = \frac{-\sqrt{D_R}+1}{\sqrt{D_R}+1} = \frac{1-\sqrt{D_R}}{1+\sqrt{D_R}}$$

$$V_{cg} = 2\pi r\omega \qquad \frac{2\pi r\omega}{V_{ag}} = \frac{1-\sqrt{D_R}}{1+\sqrt{D_R}}$$ now in terms of rotational velocity

$$\frac{\omega}{V_{ag}} = \frac{1-\sqrt{D_R}}{1+\sqrt{D_R}}\frac{1}{2\pi r}$$

Units must have the same length and time units, ie meters & seconds m/s, revolutions/s & m.

example with conical cups and 5cm radius



0.75

1.35 drag coefficients

$$\sqrt{D_R} = \sqrt{\frac{0.75}{1.35}} = 0.745$$

Dr = drag coefficient ratio

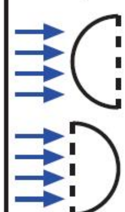
$$\frac{\omega}{V_{ag}} = \frac{1-0.745}{1+0.745}\frac{1}{2\pi 0.05m} = 0.465$$

$$\omega = 0.465\,V_{ag}$$

rotational frequency at 10mph (4.47m/s)

$$\omega = 0.465 \times 4.47m/s = 2.079Hz$$
$$2.079Hz \times 60min/Hz = 124.7rpm$$

example with hemisperical cups and 5cm radius



0.38

1.42 drag coefficients

$$\sqrt{D_R} = \sqrt{\frac{0.38}{1.42}} = 0.517$$

Dr = drag coefficient ratio

$$\frac{\omega}{V_{ag}} = \frac{1-0.517}{1+0.517}\frac{1}{2\pi 0.05m} = 1.013$$

$$\omega = 1.013\,V_{ag}$$

rotational frequency at 10mph (4.47m/s)

$$\omega = 1.013 \times 4.47m/s = 4.528Hz$$
$$4.528Hz \times 60min/Hz = 271.7rpm$$