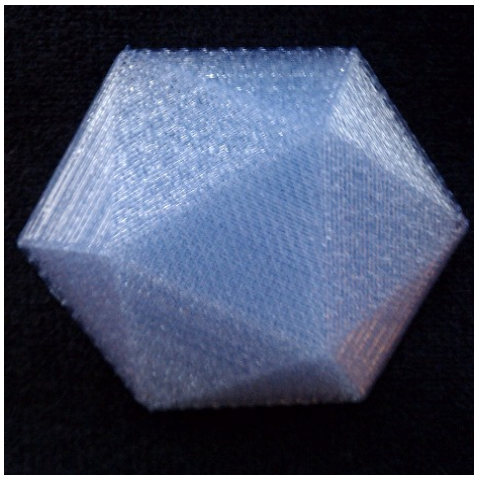
3D Printing Projects for Math Majors

Edward F. Aboufadel

Grand Valley State University



Outline of Talk: What Can a Math Major Do?

Mathematica

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Project Ideas for Multivariable Calculus

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Project Ideas for College Geometry

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Eugenia Cheng's Associahedron

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Other Project Ideas

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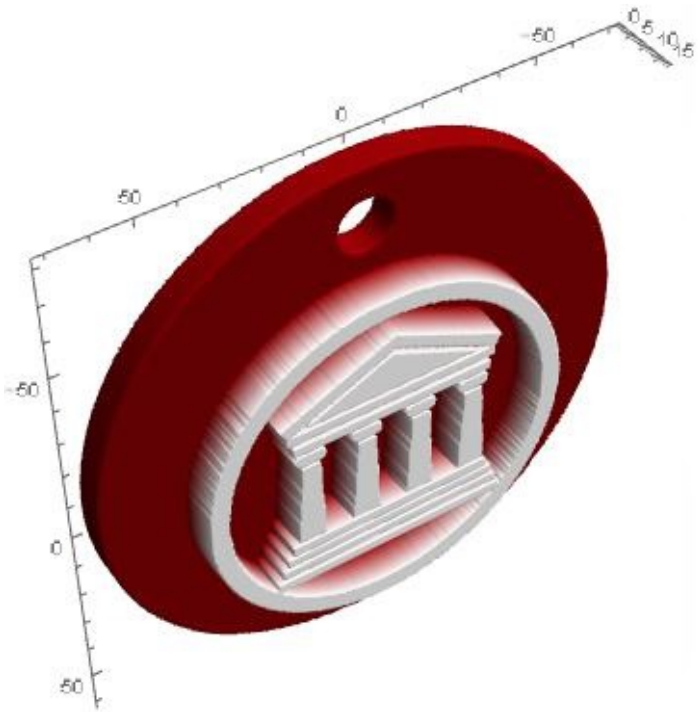
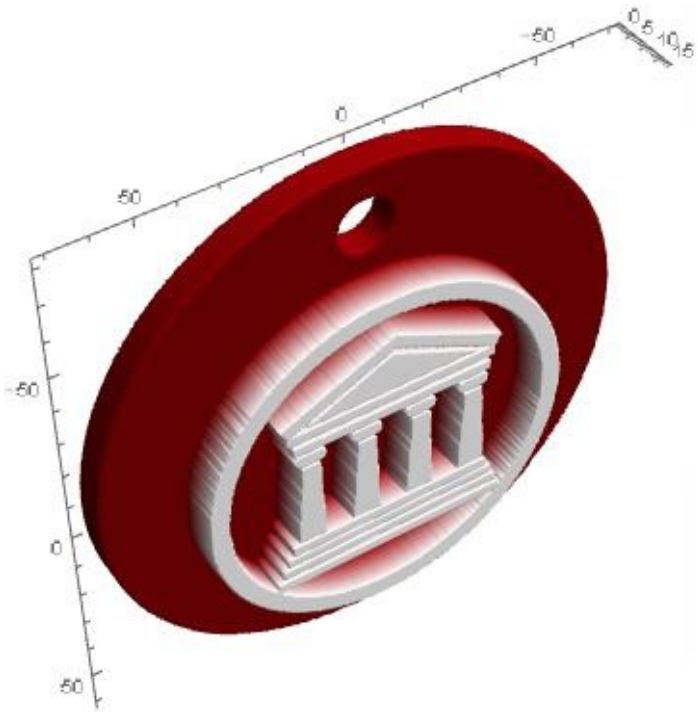
For Further Information

Mathematica



Generate 3D objects and export as STL

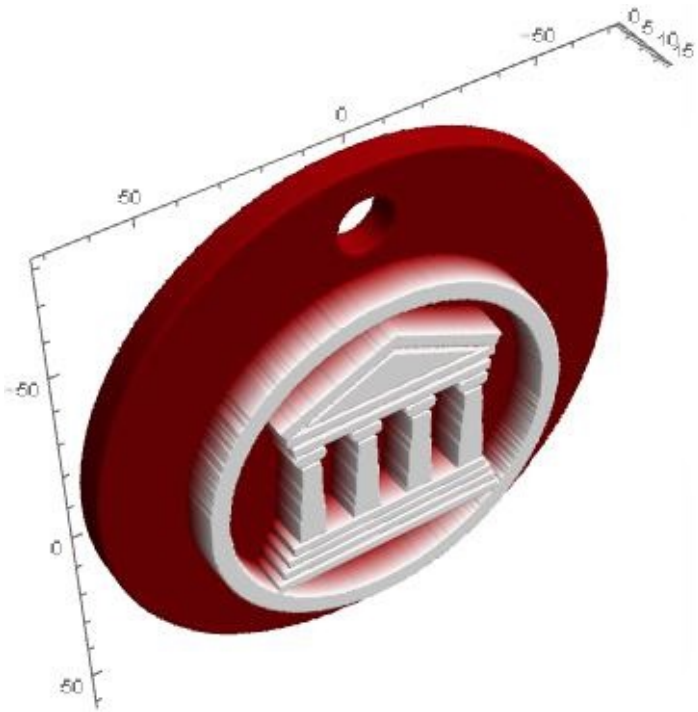
Mathematica



Generate 3D objects and export as STL

Define and render $z = f(x, y)$

Mathematica



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Define and render $z = f(x, y)$

Import and process images for use in designs

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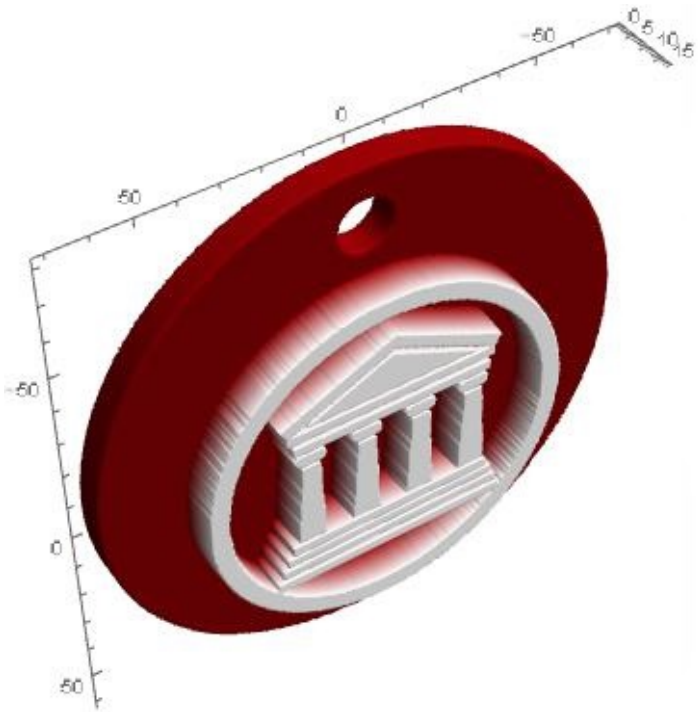

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Define and render $z = f(x, y)$

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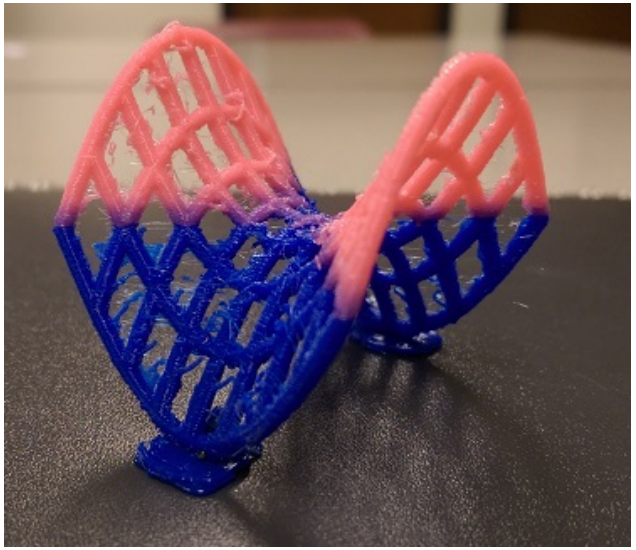
Multi. Calc: $z = f(x, y)$ surfaces



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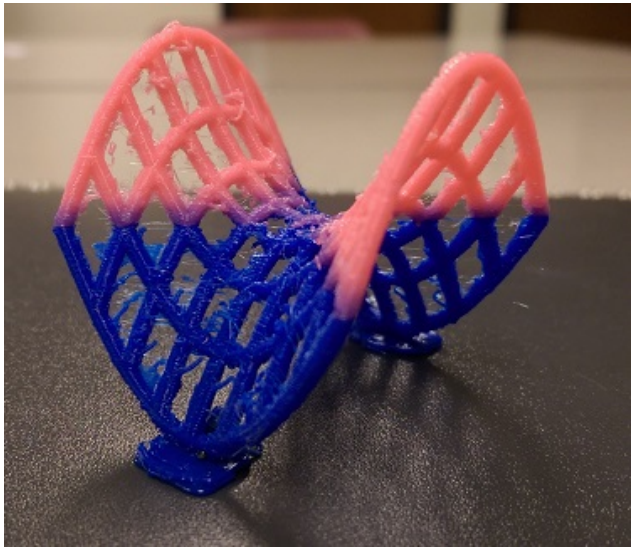

Inspired by David Bachman's designs.

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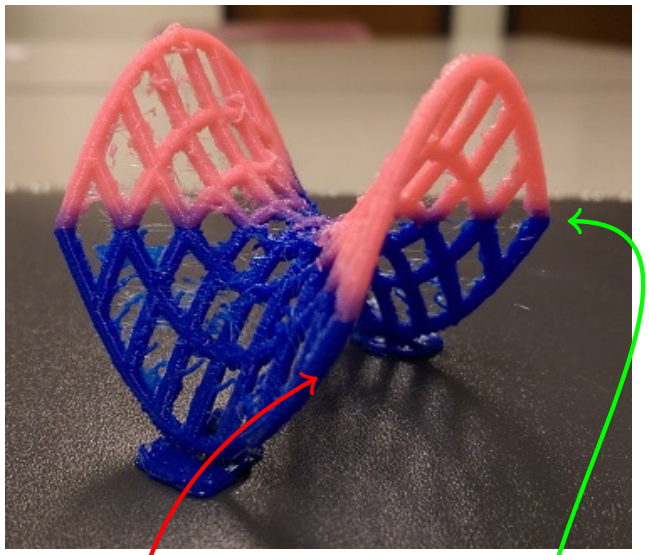

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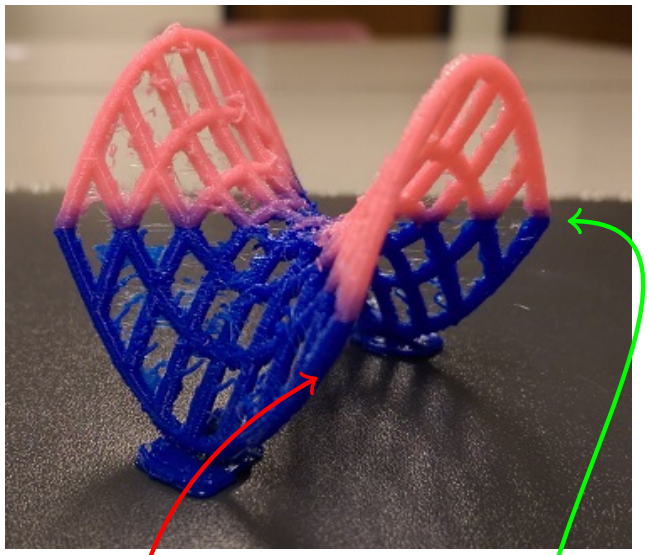
Defined by a union of tubes and small spheres to generate a grid-like representation of the surface.

Multi. Calc: $z = f(x, y)$ surfaces



Inspired by David Bachman's designs.

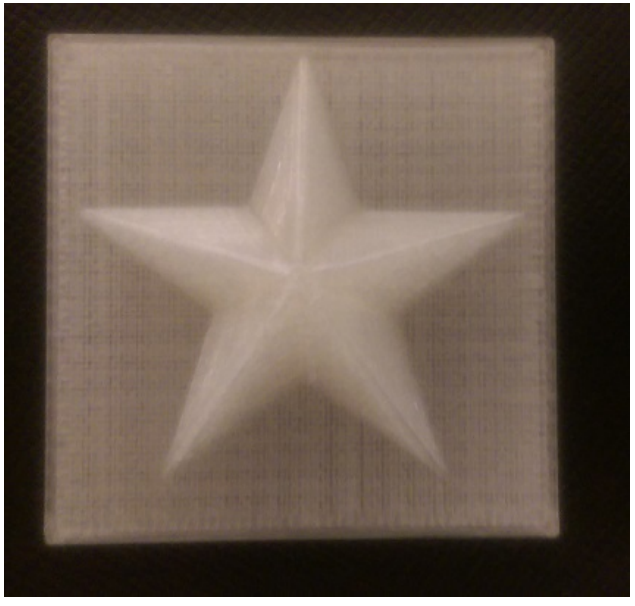
Defined by a union of tubes and small spheres to generate a grid-like representation of the surface.

Implementation comes from Henry Segerman's "3D Printing for Mathematical Visualization". *Mathematica* code is available in Segerman's paper.

Multi. Calc: $z = f(x, y)$ surfaces

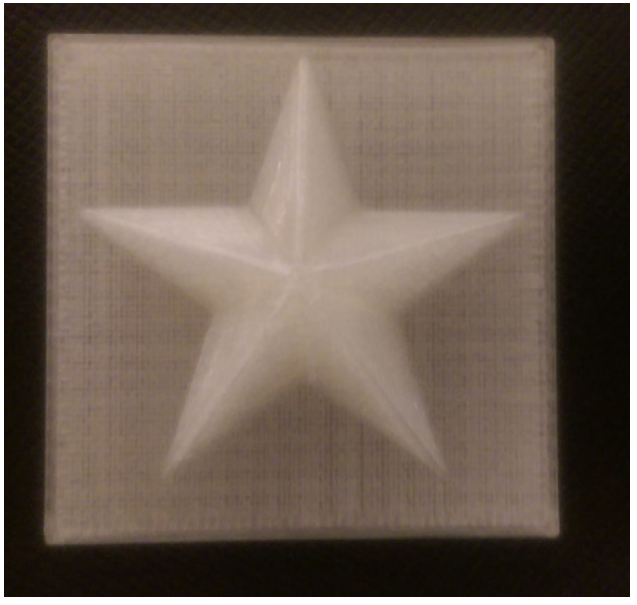
Created by Washington & Lee University student Emily Jaekle, working with Prof. Elizabeth Denne. Available on the Thingiverse.

Multi. Calc: The Star Project – Joining Several Planes



Multi. Calc: The Star Project – Joining Several Planes

Thank you to Lindsay Czap (GVSU student)



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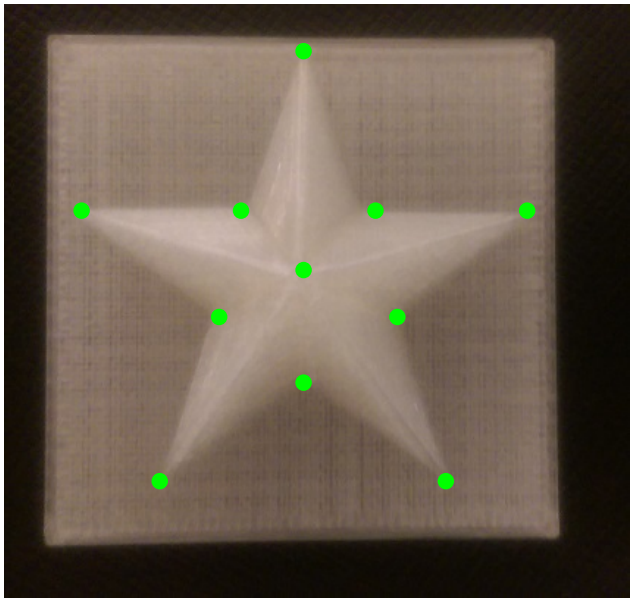
Key coordinates



Multi. Calc: The Star Project – Joining Several Planes

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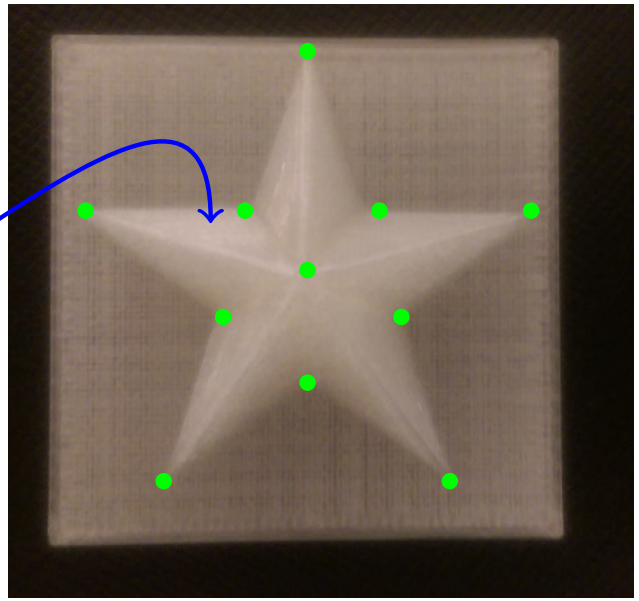
Key coordinates

One of ten planes



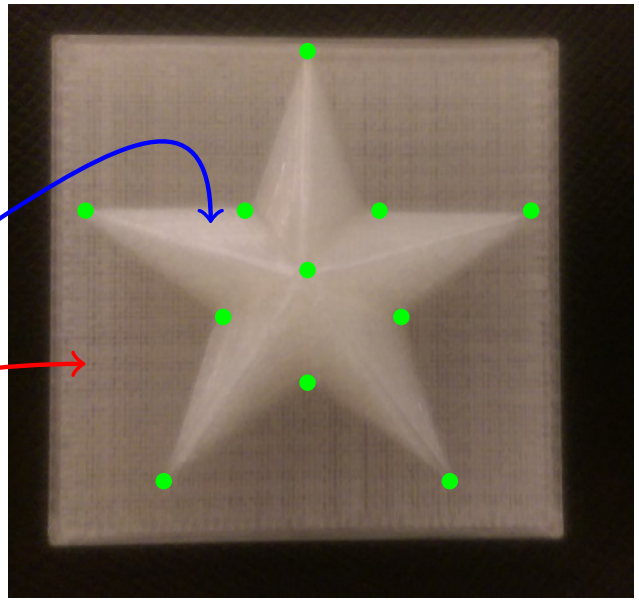
Multi. Calc: The Star Project – Joining Several Planes

Thank you to Lindsay Czap (GVSU student)

Key coordinates

One of ten planes

Base



Multi. Calc: The Star Project – Joining Several Planes

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To find the equation of the plane through (x_0, y_0, z_0), (x_1, y_1, z_1), and (x_2, y_2, z_2):

$$det \begin{bmatrix} x & y & z & 1 \\ x_0 & y_0 & z_0 & 1 \\ x_1 & y_1 & z_1 & 1 \\ x_2 & y_2 & z_2 & 1 \end{bmatrix} = 0$$

and solve for z.

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Also: For each plane, need to restrict the domain to a triangle. Can use `RegionFunction` option, or three tests with determinants and the sides of the triangles.

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Also: For each plane, need to restrict the domain to a triangle. Can use `RegionFunction` option, or three tests with determinants and the sides of the triangles.

The base is generated separately, and all the pieces are joined together with `Show`.

Multi. Calc: MAA Pendant

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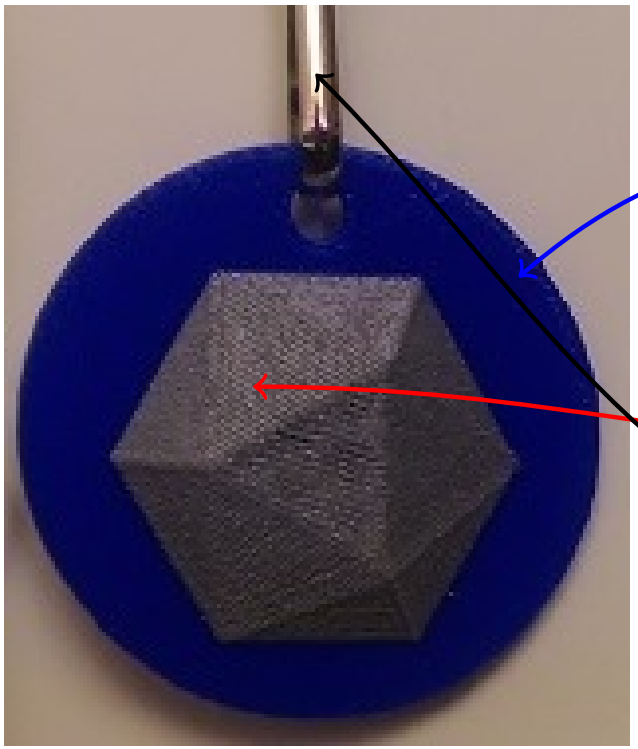

Base: a cylinder, with a restricted domain to create the hole for the clip

One of ten planes

Lanyard ordered from Amazon

College Geometry: *n*-gonal Pyramids

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Base is a regular polygon

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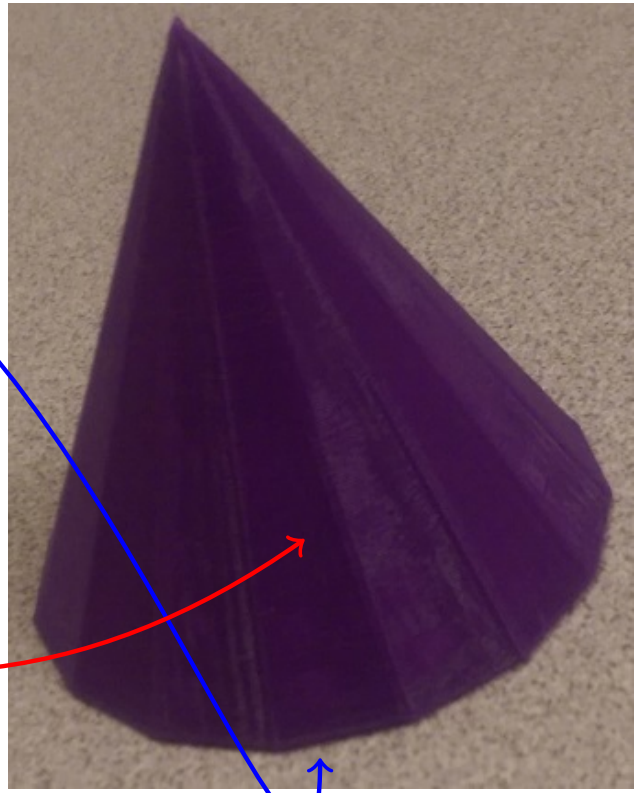
Vertices are on the unit circle – good trigonometry review

College Geometry: *n*-gonal Pyramids

Base is a regular polygon

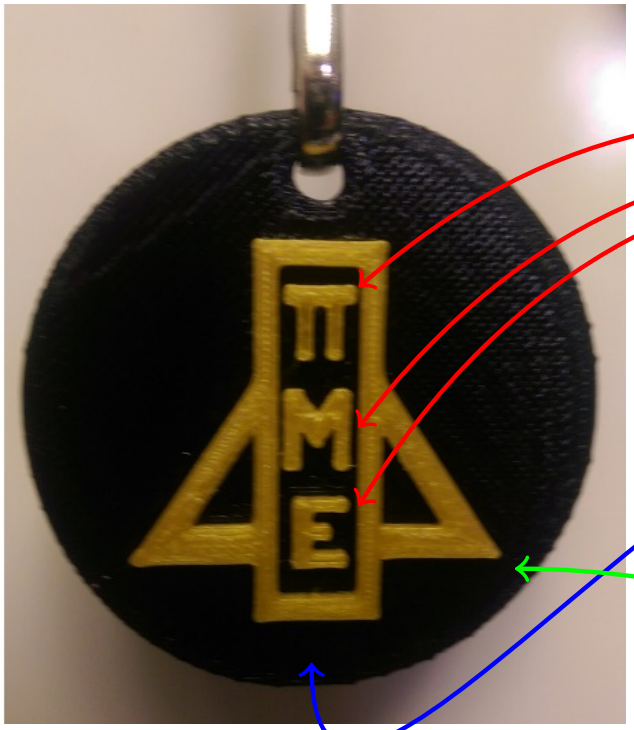
Vertices are on the unit circle – good trigonometry review

Several `Polygon` commands used to create sides



College Geometry: Pi Mu Epsilon Pendant

College Geometry: Pi Mu Epsilon Pendant



Start with a cylinder for the base.

In 2D, each letter is a (irregular) dodecahedron.

Many polygons needed to define the sides perpendicular to the xy-plane

The angles in this isosceles triangle? Location of the third vertex?

College Geometry: Mini Maker Faire

A. Make a geometric object from a set of choices (including "Make A Counter Offer").

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C. Write a short paper (3-5 pages) describing your work, with mathematical details. I expect you'll have to do a bit of research on your topic to make your paper top-notch.

College Geometry: Mini Maker Faire

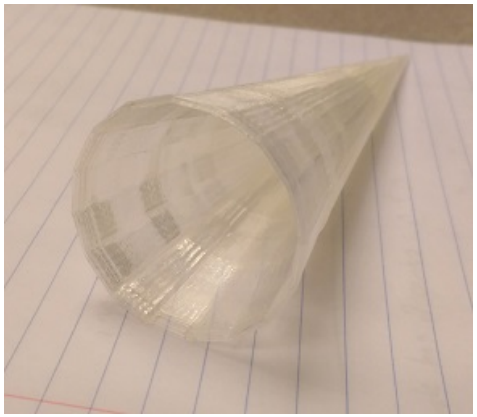
A. Make a geometric object from a set of choices (including "Make A Counter Offer").

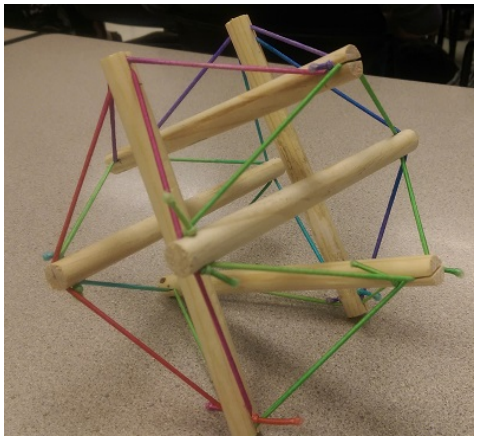
B. Extend your work creatively to create another object.

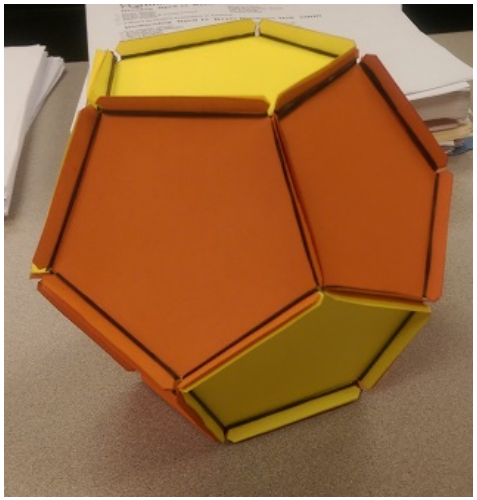
C. Write a short paper (3-5 pages) describing your work, with mathematical details. I expect you'll have to do a bit of research on your topic to make your paper top-notch.

D. Give a five-minute presentation about your project to the class during the week of April 13.

College Geometry: Mini Maker Faire







Eugenia Cheng

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Mathematician, pianist, minor celebrity

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University of Sheffield & the School of Art Institute of Chicago

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Mathematician, pianist, minor celebrity

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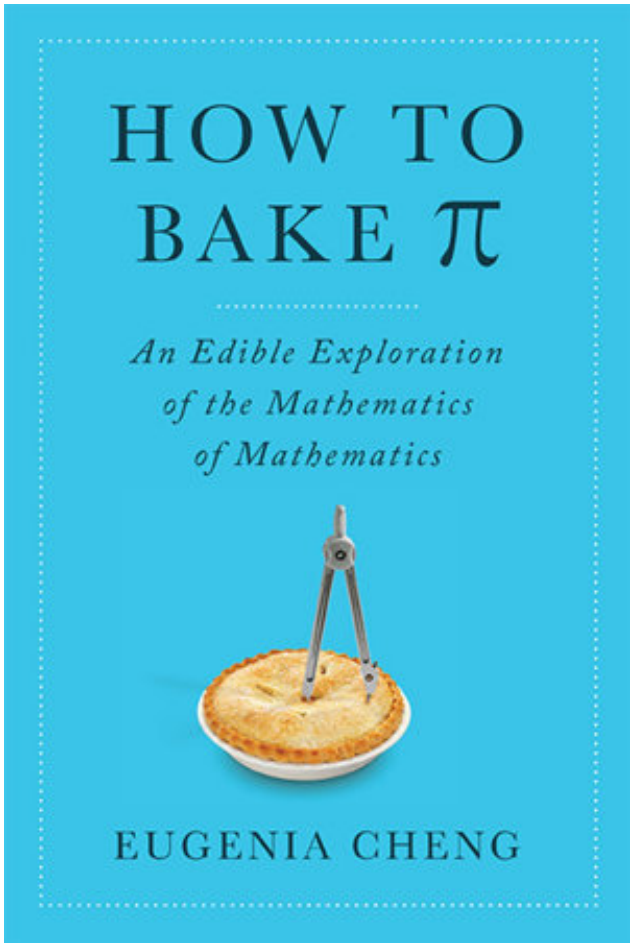
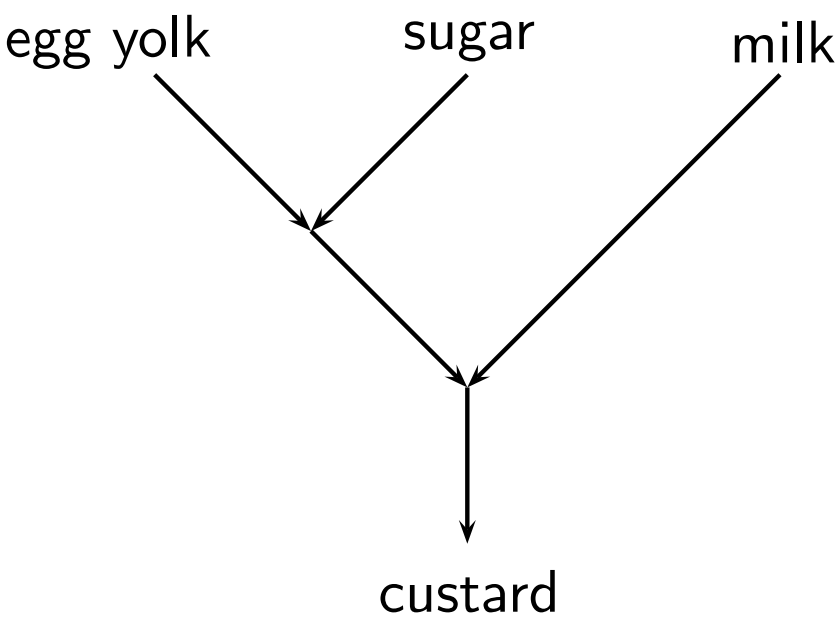
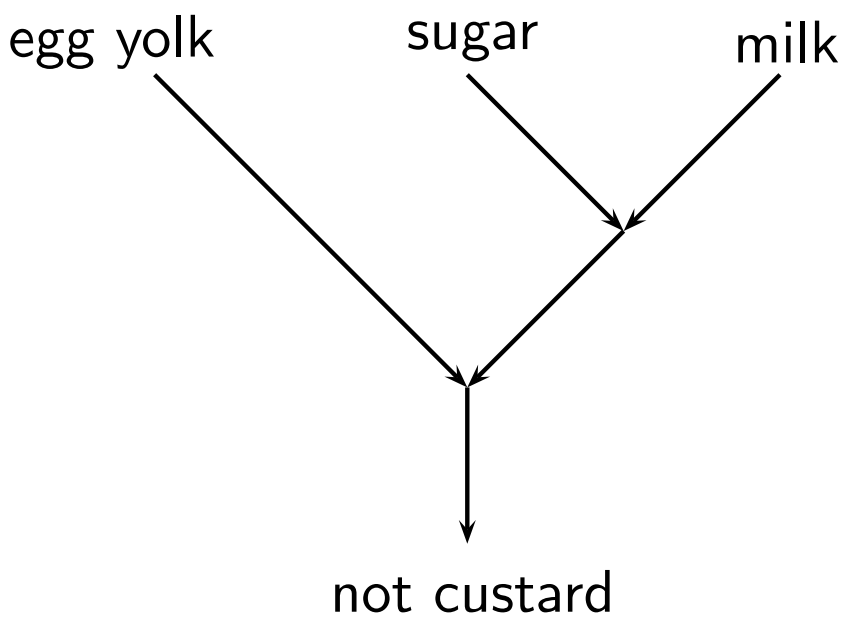
Specialist in category theory

An Edible Exploration of the Mathematics of Mathematics



Mixing Ingredients to Make Custard





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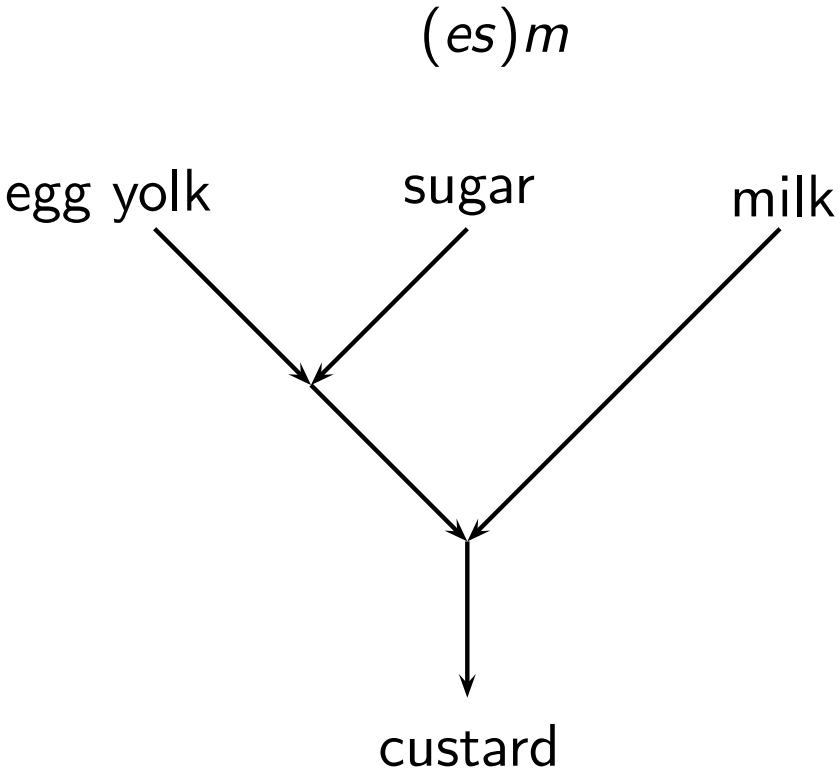
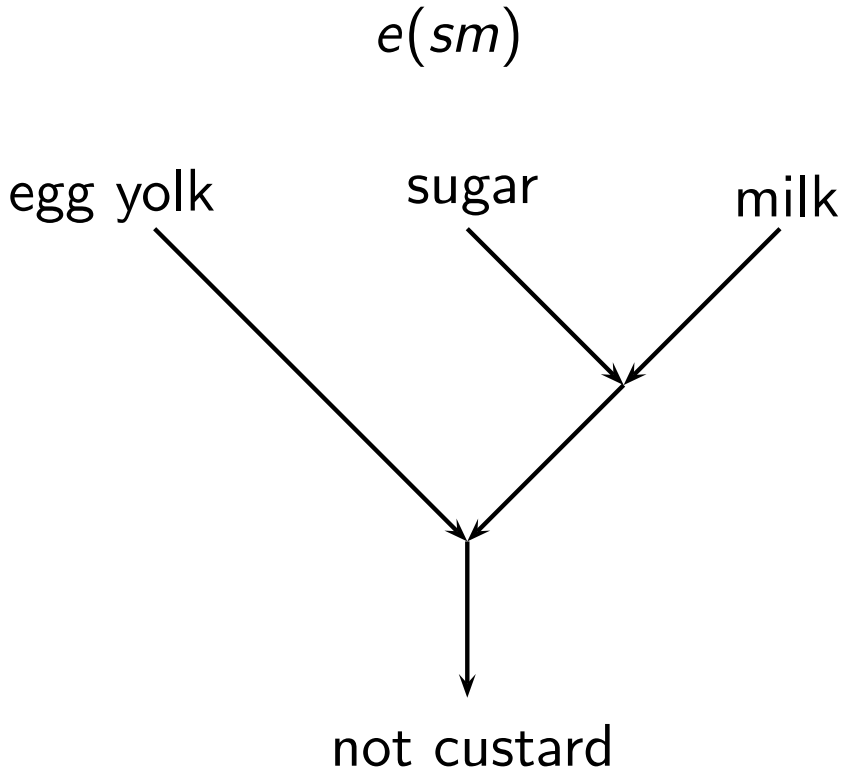




Mixing Five Ingredients

Label	*Coordinates*	*Tree*
A	$(0, \frac{1}{2})$	$(12)(3(45))$
B	$(\alpha, \beta + \frac{1}{2})$	$(12)((34)5)$
C	$(\gamma, 0)$	$((12)(34))5$
D	$(\alpha, -\beta - \frac{1}{2})$	$(((12)3)4)5$
E	$(0, -\frac{1}{2})$	$((12)3)(45)$
F	$(-\beta, -\alpha - \frac{1}{2})$	$(1(23))(45)$
F'	$(-\alpha, -\beta - \frac{1}{2})$	...
G	$(\alpha - \beta, -\alpha - \beta - \frac{1}{2})$	$((1(23))4)5$
G'	$(\gamma, -2\beta - 1)$	...
G''	$(-\gamma, -2\beta - 1)$	...
H	$(\alpha + \gamma, -\beta - 1)$	$(1((23)4))5$
H'	$(-\alpha - \gamma - 1, \beta)$	...
H''	$(-\alpha - \gamma, -\beta - 1)$	...

Label	*Coordinates*	*Tree*
I	$(\alpha + \gamma, \beta)$	$(1(2(34)))5$
I'	$(\alpha + \gamma, -\beta)$	...
I''	$(-\alpha - \gamma - 1, \beta + 1)$	...
J	$(\alpha + \gamma, \beta + 1)$	$1((2(34))5)$
J'	$(-\alpha - \gamma, \beta + 1)$	...
K	$(\gamma, 2\beta + 1)$	$1(2((34)5))$
K'	$(\alpha - \beta, \alpha + \beta + \frac{1}{2})$	...
K''	$(-\gamma, 2\beta + 1)$	...
L	$(-\beta, \alpha + \frac{1}{2})$	$1(2(3(45)))$
L'	$(-\alpha, \beta + \frac{1}{2})$	...
M	$(-\gamma, 0)$	$1((23)(45))$
N	$(-\alpha - \gamma, \beta)$	$1(((23)4)5)$
N'	$(-\alpha - \gamma, -\beta)$	...

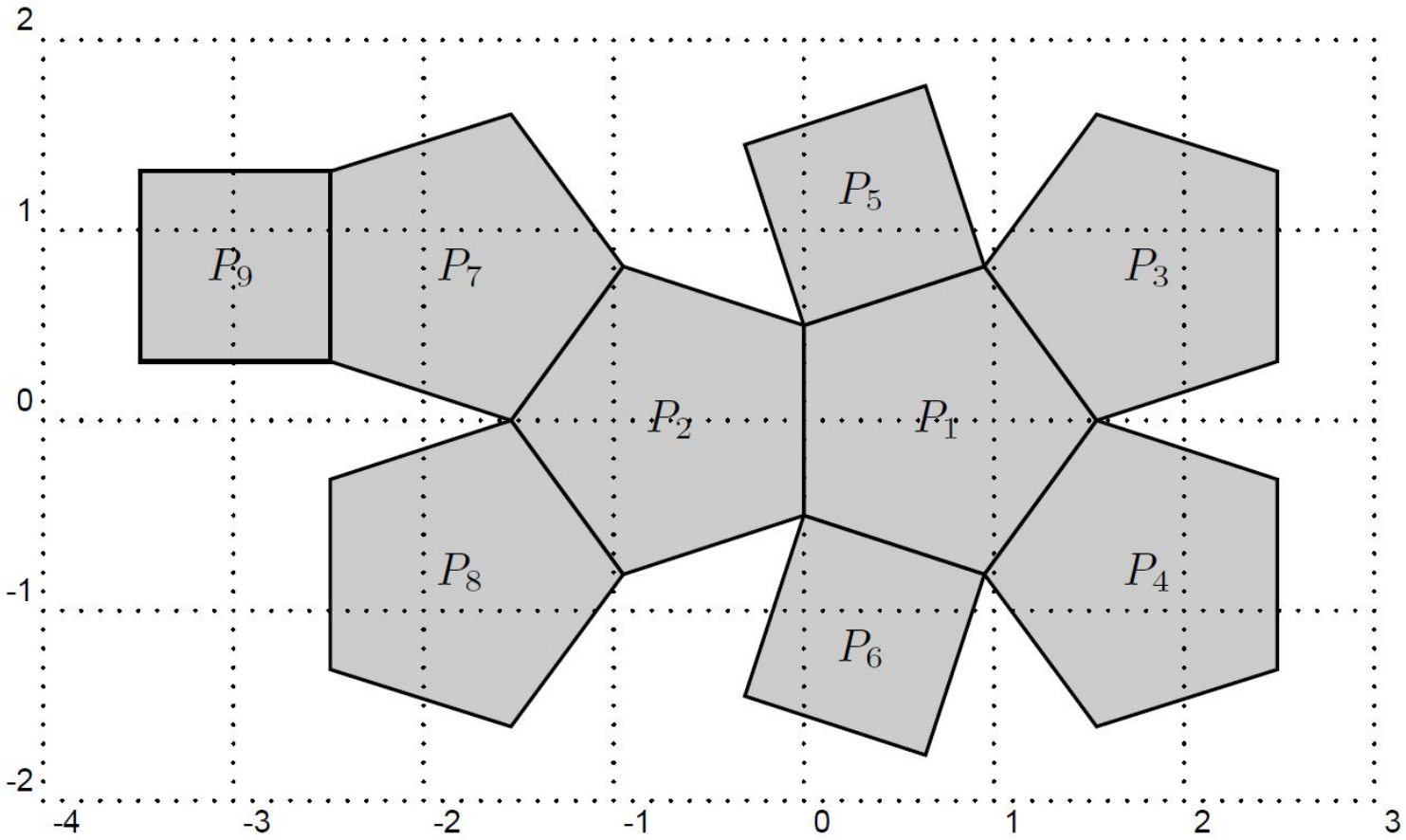
Defining Polyhedra

Label	*Coordinates*	*Tree*
A	$(0, \frac{1}{2})$	$(12)(3(45))$
B	$(\alpha, \beta + \frac{1}{2})$	$(12)((34)5)$
C	$(\gamma, 0)$	$((12)(34))5$
D	$(\alpha, -\beta - \frac{1}{2})$	$(((12)3)4)5$
E	$(0, -\frac{1}{2})$	$((12)3)(45)$
F	$(-\beta, -\alpha - \frac{1}{2})$	$(1(23))(45)$
F'	$(-\alpha, -\beta - \frac{1}{2})$	...
G	$(\alpha - \beta, -\alpha - \beta - \frac{1}{2})$	$((1(23))4)5$
G'	$(\gamma, -2\beta - 1)$	...
G''	$(-\gamma, -2\beta - 1)$	...
H	$(\alpha + \gamma, -\beta - 1)$	$(1((23)4))5$
H'	$(-\alpha - \gamma - 1, \beta)$	...
H''	$(-\alpha - \gamma, -\beta - 1)$	...

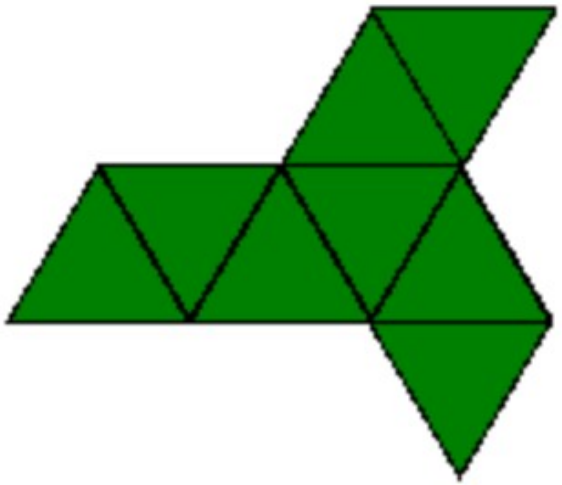
Label	*Coordinates*	*Tree*
I	$(\alpha + \gamma, \beta)$	$(1(2(34)))5$
I'	$(\alpha + \gamma, -\beta)$	...
I''	$(-\alpha - \gamma - 1, \beta + 1)$	...
J	$(\alpha + \gamma, \beta + 1)$	$1((2(34))5)$
J'	$(-\alpha - \gamma, \beta + 1)$	...
K	$(\gamma, 2\beta + 1)$	$1(2((34)5))$
K'	$(\alpha - \beta, \alpha + \beta + \frac{1}{2})$	...
K''	$(-\gamma, 2\beta + 1)$	...
L	$(-\beta, \alpha + \frac{1}{2})$	$1(2(3(45)))$
L'	$(-\alpha, \beta + \frac{1}{2})$	...
M	$(-\gamma, 0)$	$1((23)(45))$
N	$(-\alpha - \gamma, \beta)$	$1(((23)4)5)$
N'	$(-\alpha - \gamma, -\beta)$	...

Note: $\alpha = \cos(18°)$, $\beta = \sin(18°)$, and $\gamma = \frac{\cot(36°)}{2} + \frac{\csc(36°)}{2} = \frac{1+\cos(36°)}{2\sin(36°)}$. Then, the polygons are: $P_1 = \{A, B, C, D, E\}$

Cheng's Net



A Simpler Net



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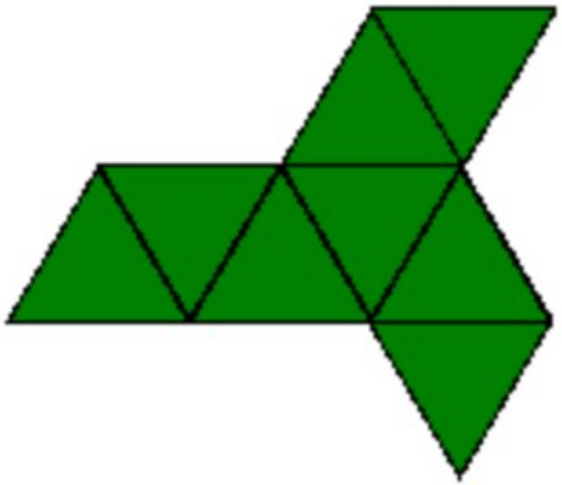
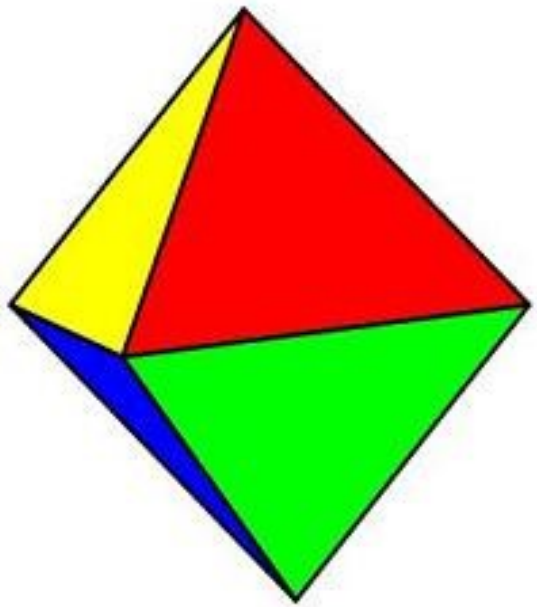
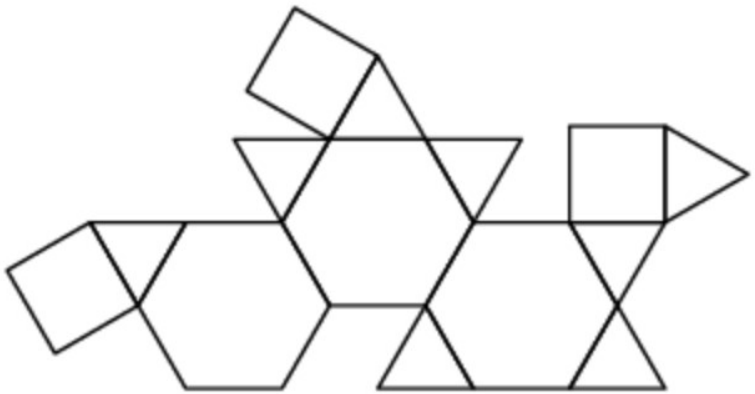




A More Complicated Net



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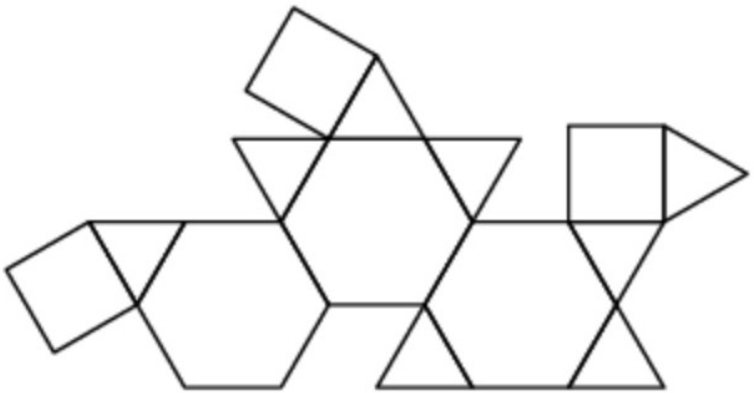
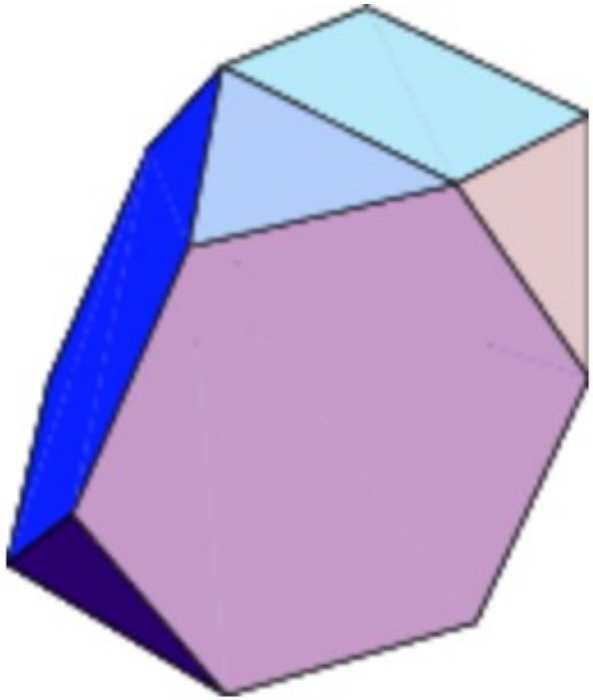
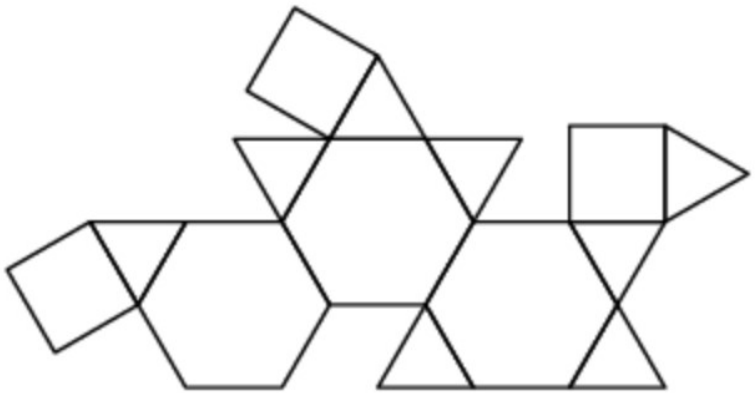
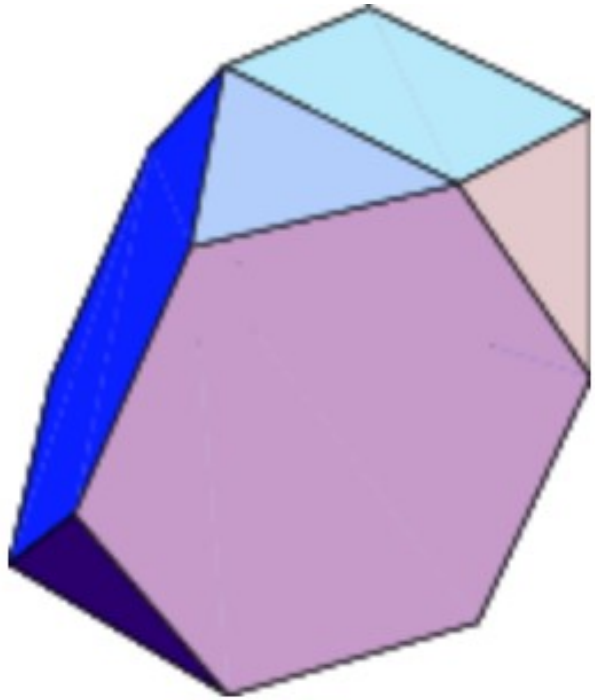




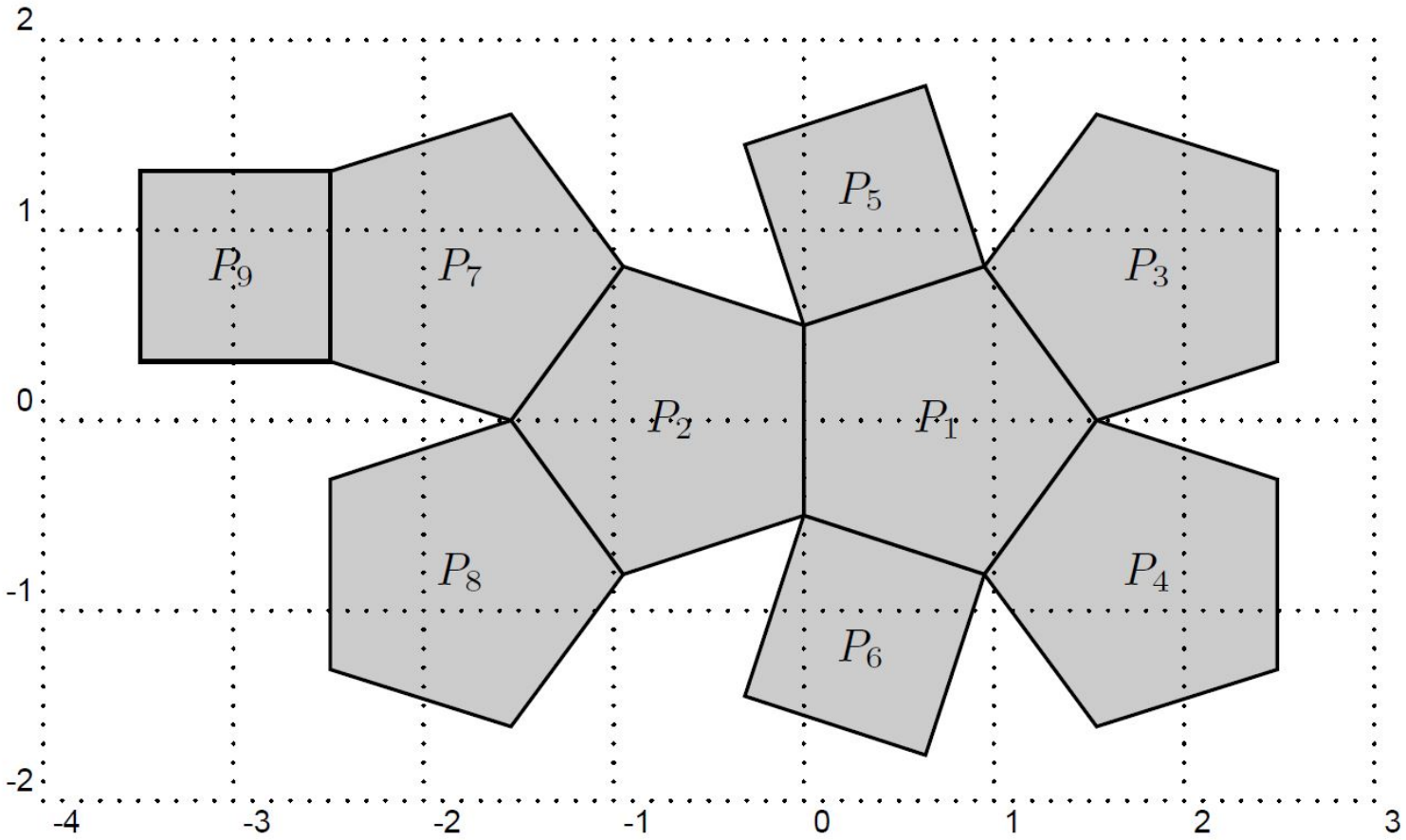
A More Complicated Net





Augmented Truncated Tetrahedron

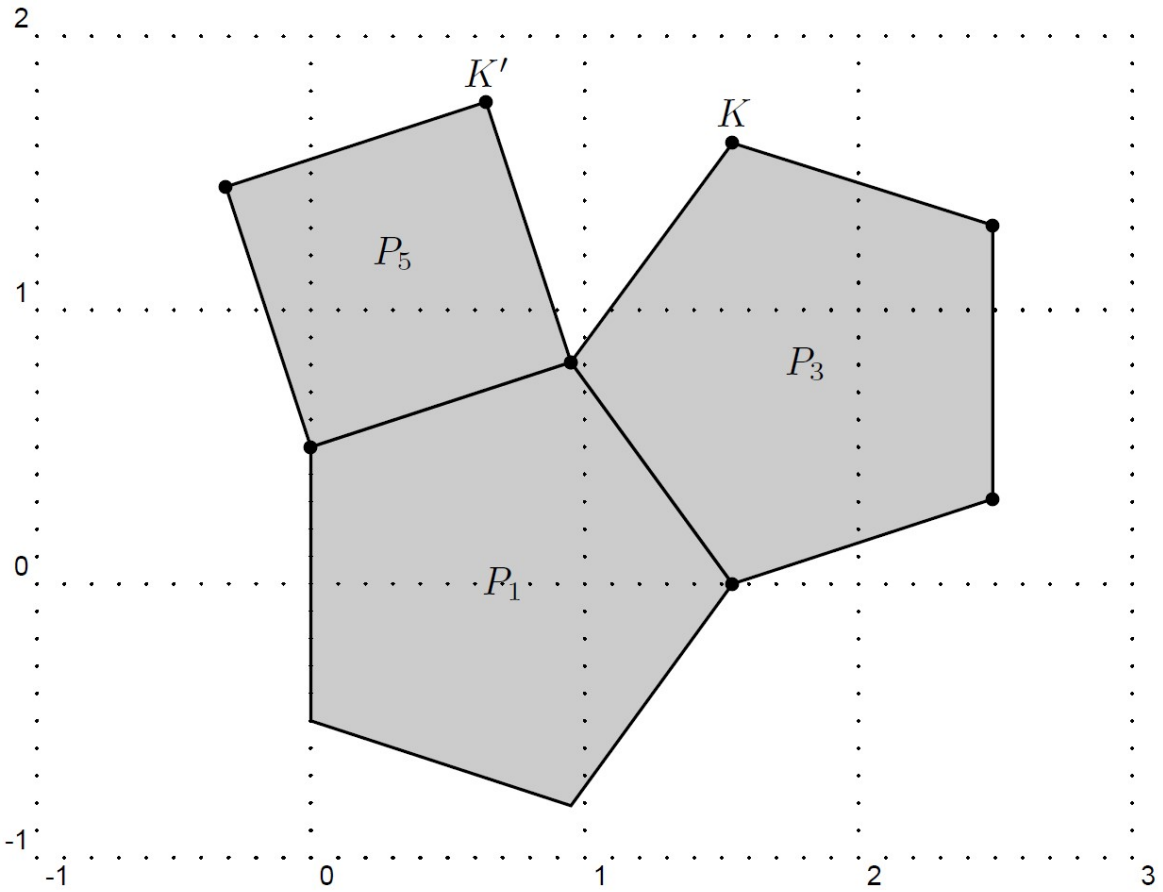
Cheng's Net



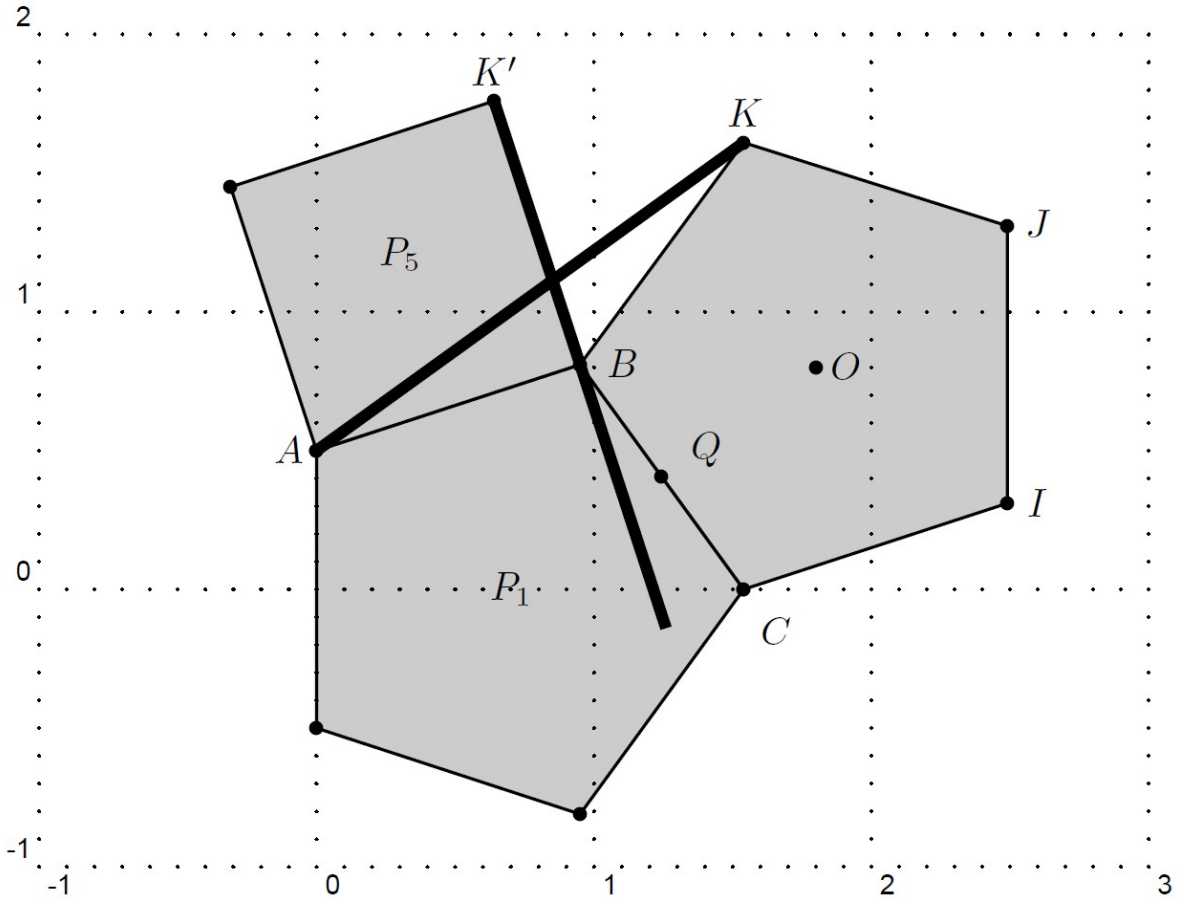
Wonky?

Just don't try to make it out of thick card stock, because it won't quite fit together – it needs to be made from paper that's a bit bendy, otherwise the pentagon and squares would have to be a bit wonky for them all to fit together. – E. Cheng

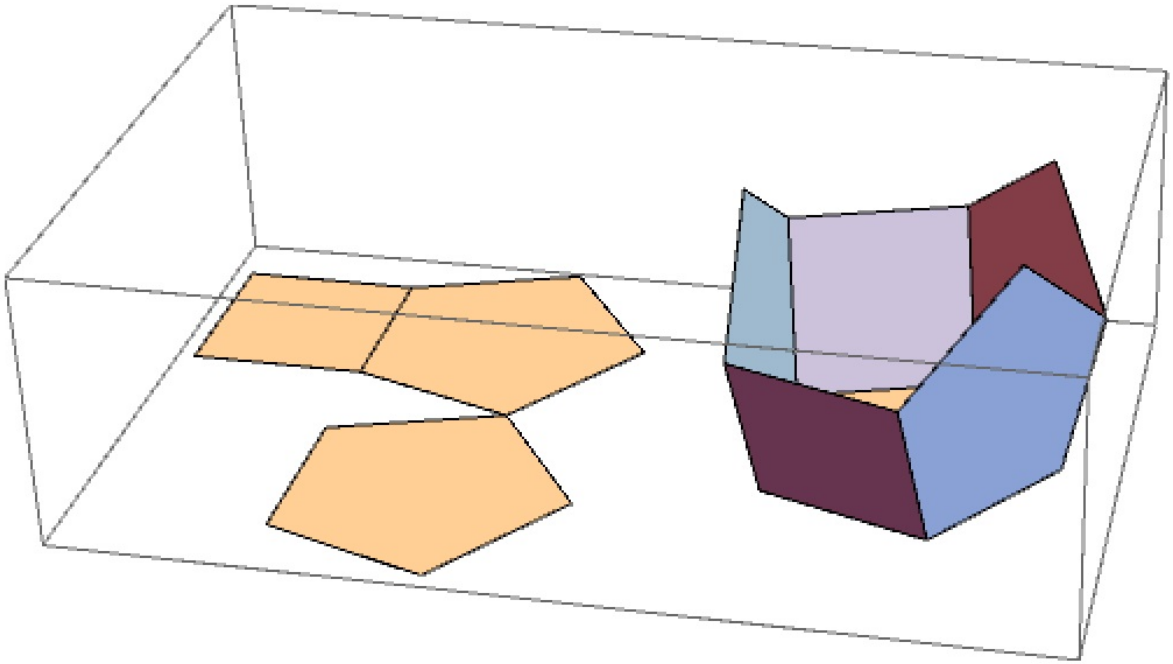
Folding Cheng's Net



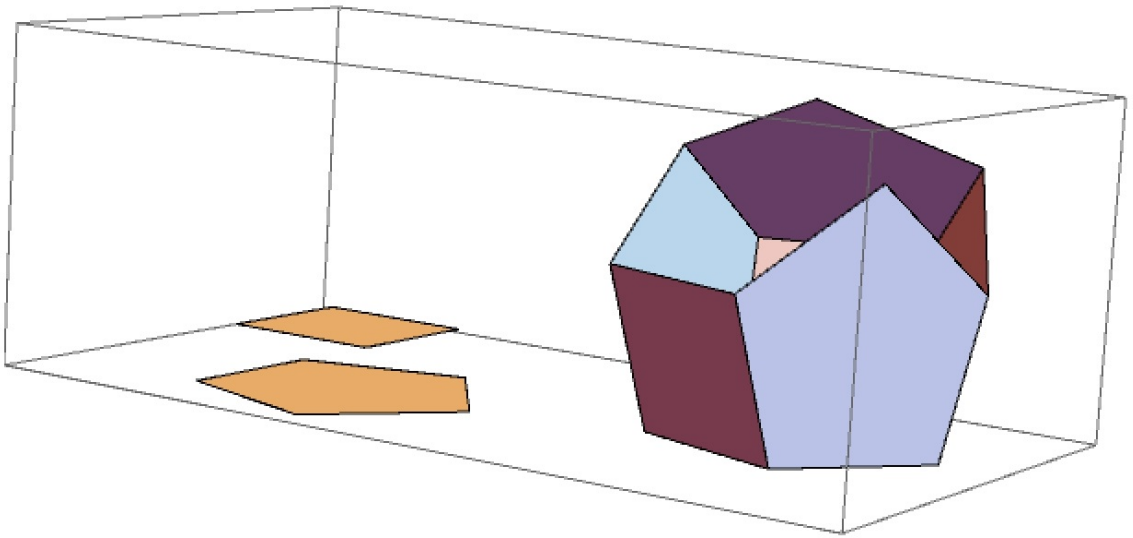
Folding Cheng's Net



Folding Cheng's Net



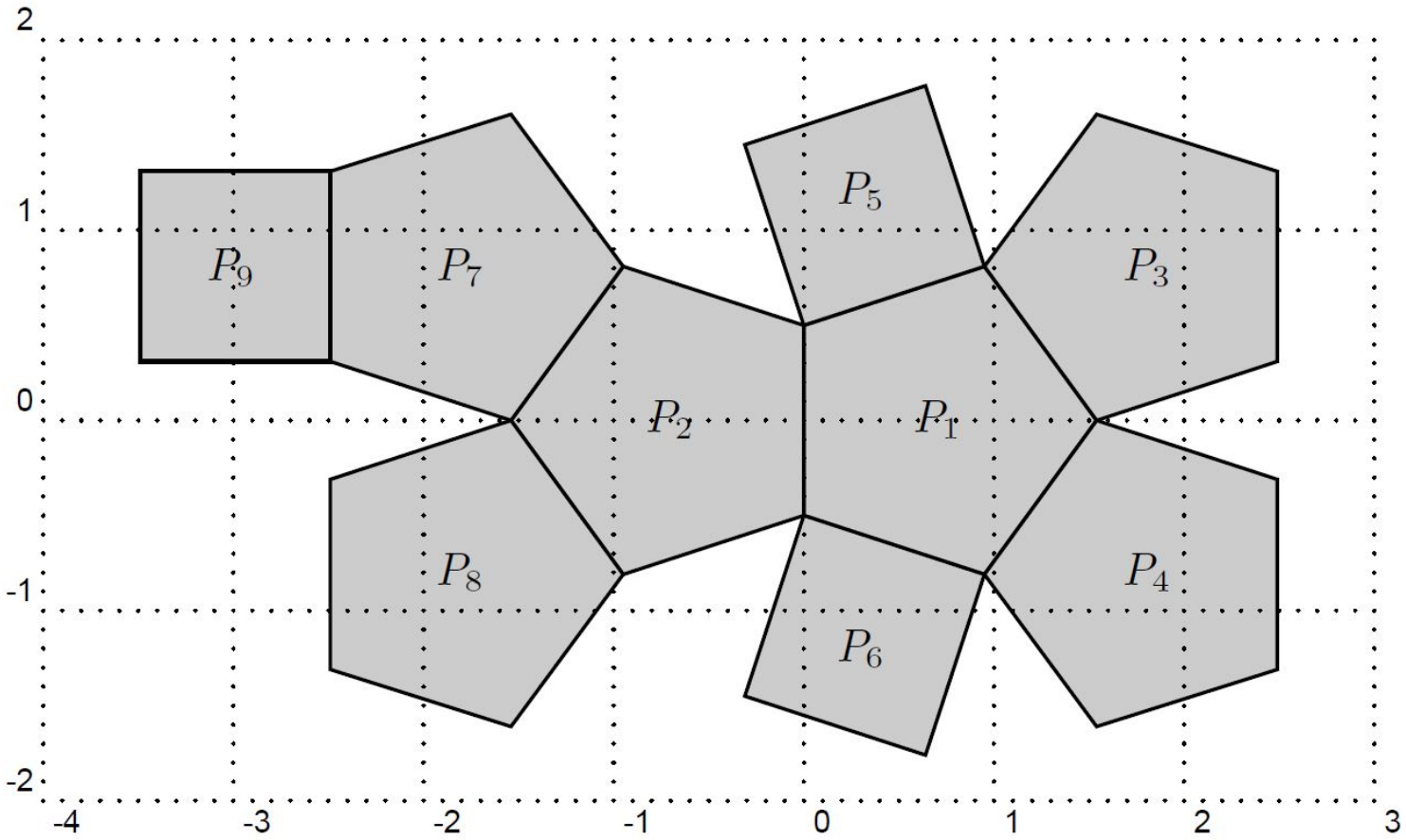
Folding Cheng's Net



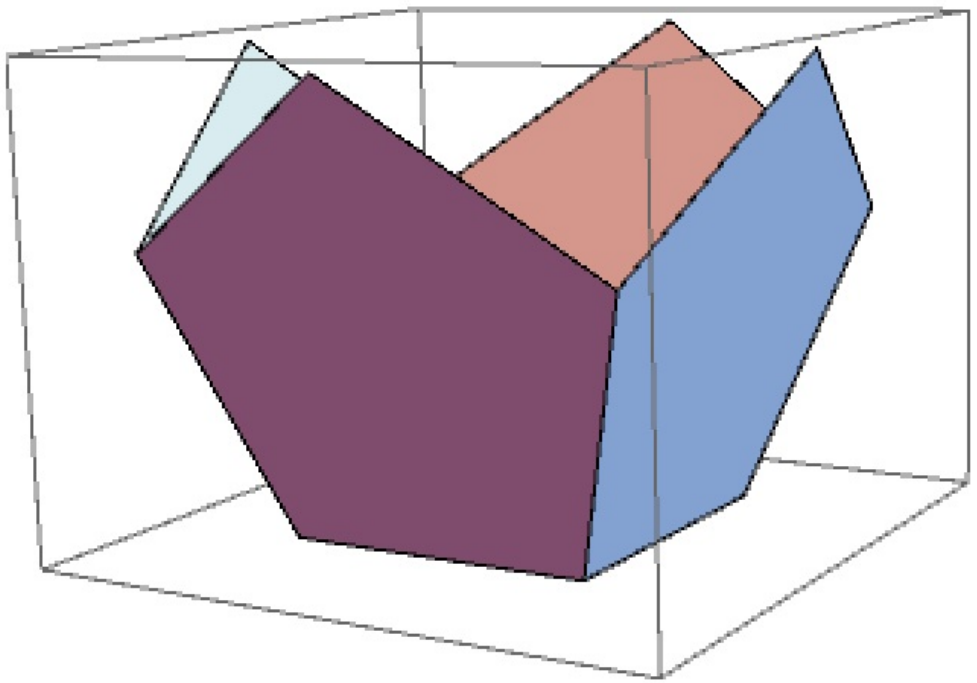
Cheng's Associahedron

Thank you to Samantha Law (GVSU student)

Cheng's Net



Alternate Build



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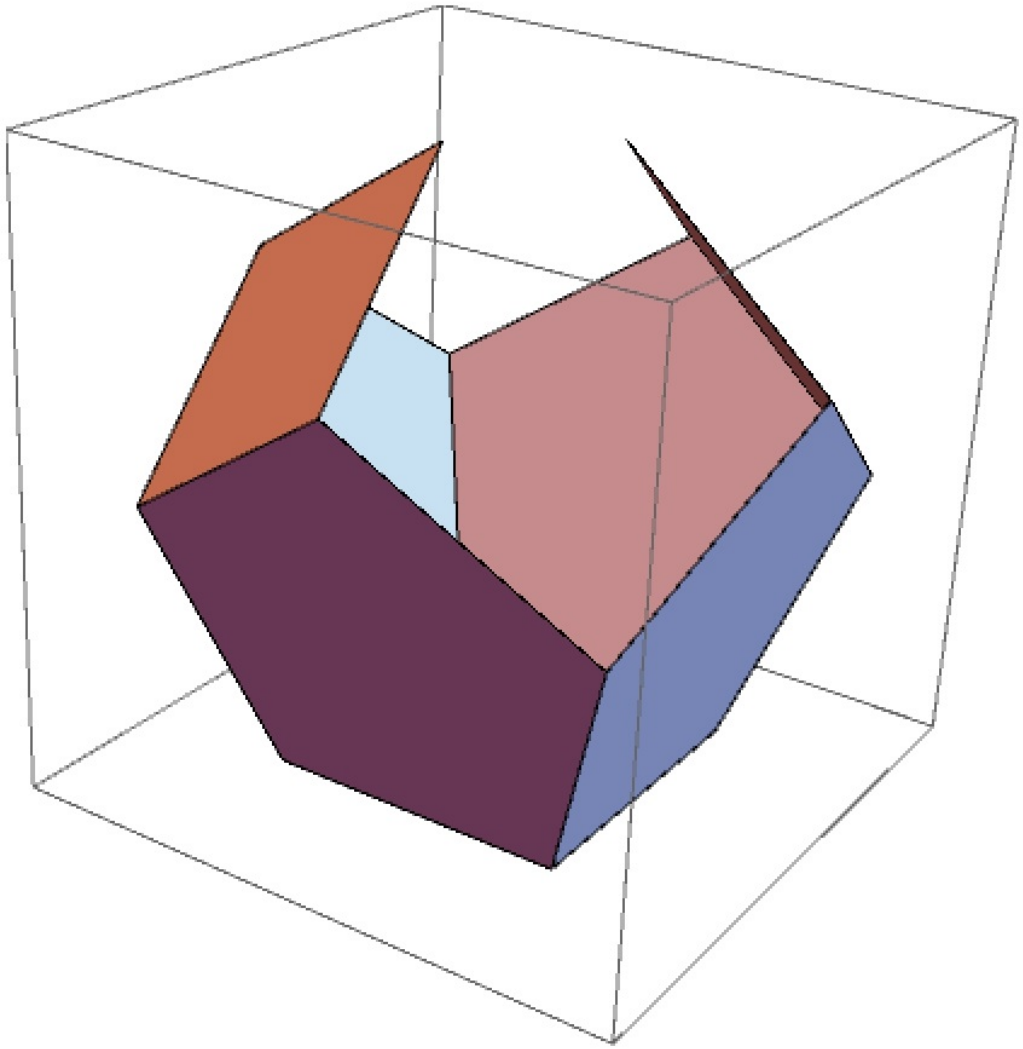
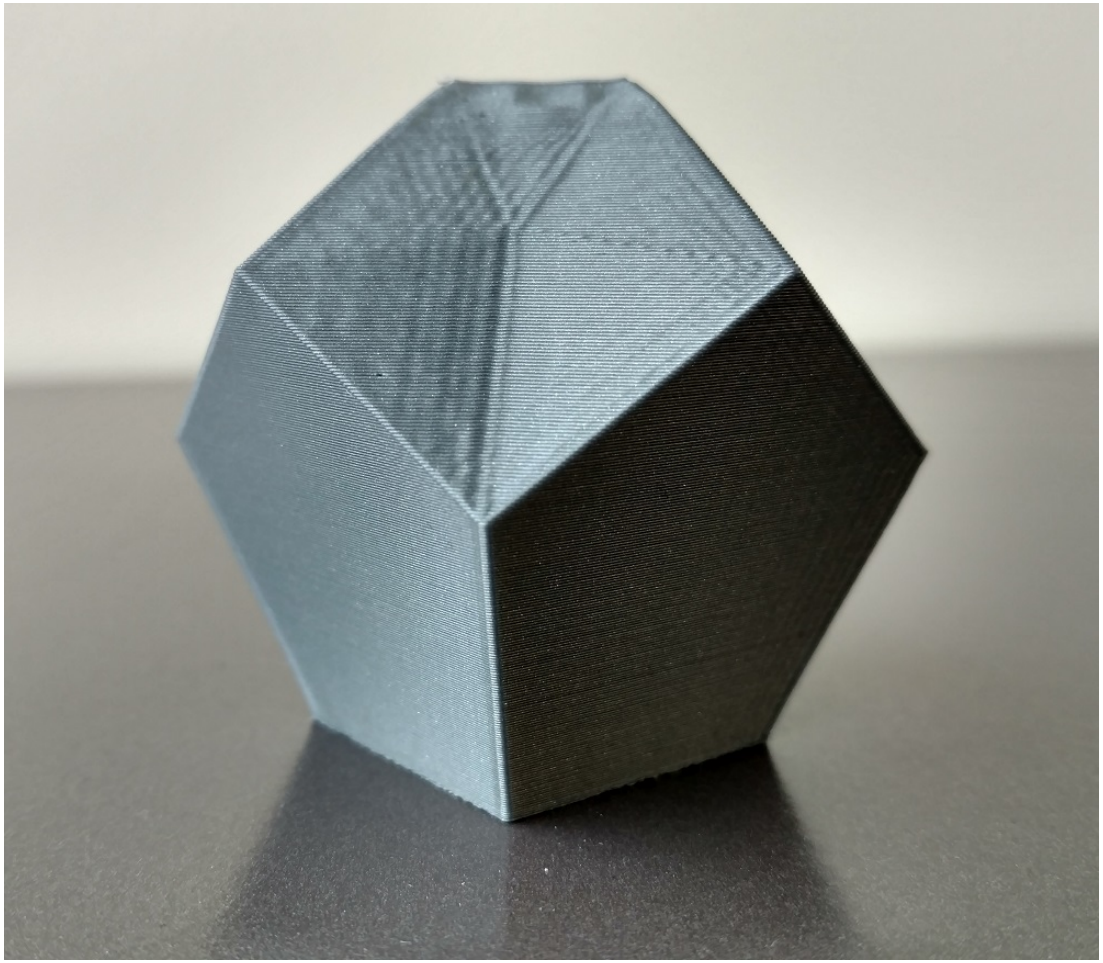


Alternate Build

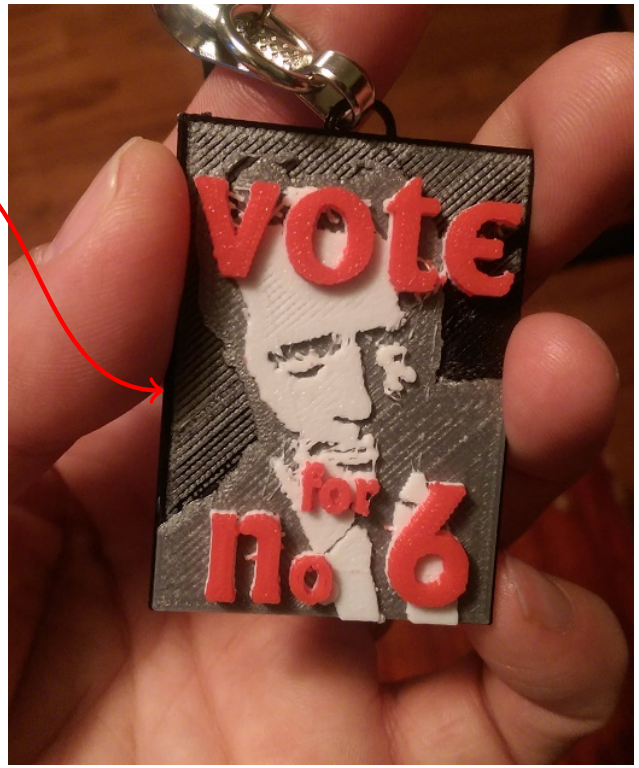


3D Bliss

Vote for Number 6

Vote for Number 6

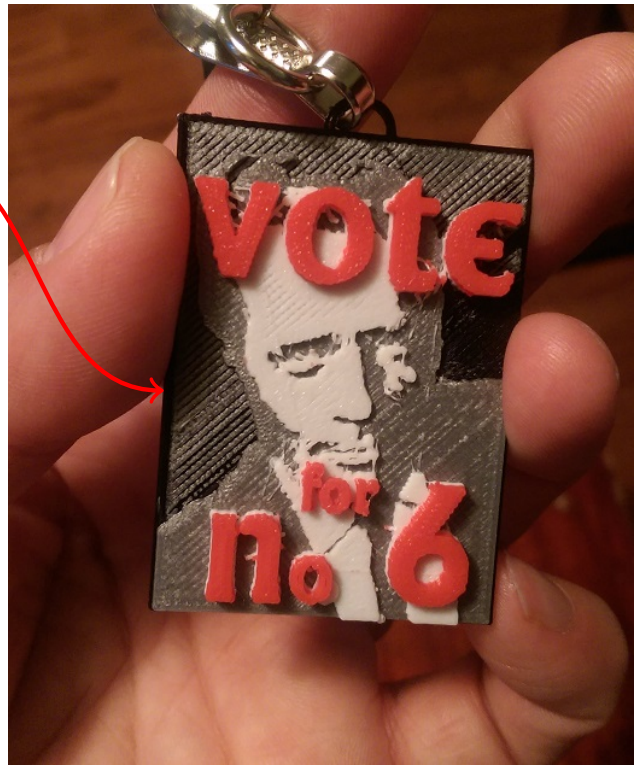
Load images into Mathematica



Vote for Number 6

Load images into Mathematica

Significant pre-processing (and Mathematica processing) of image is needed.



Vote for Number 6

Load images into Mathematica

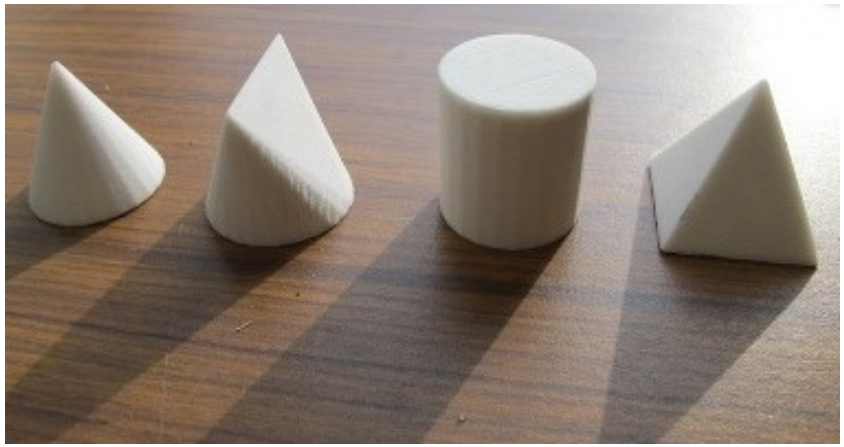
Significant pre-processing (and Mathematica processing) of image is needed.

This hook is the difference of two cylinders

Other ideas for courses, independent studies

Linear transformations of 3D objects – effect on printability, printing speeds, volume used, etc.

Re-create work of Hart, Segerman, Knill, Taalman, etc.



For More Information



- Short "how-to" papers, STL files, some Mathematica code, and links to other sites (including my Thingiverse page): sites.google.com/site/aboufadelreu.