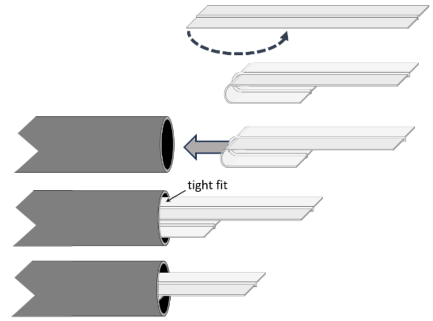
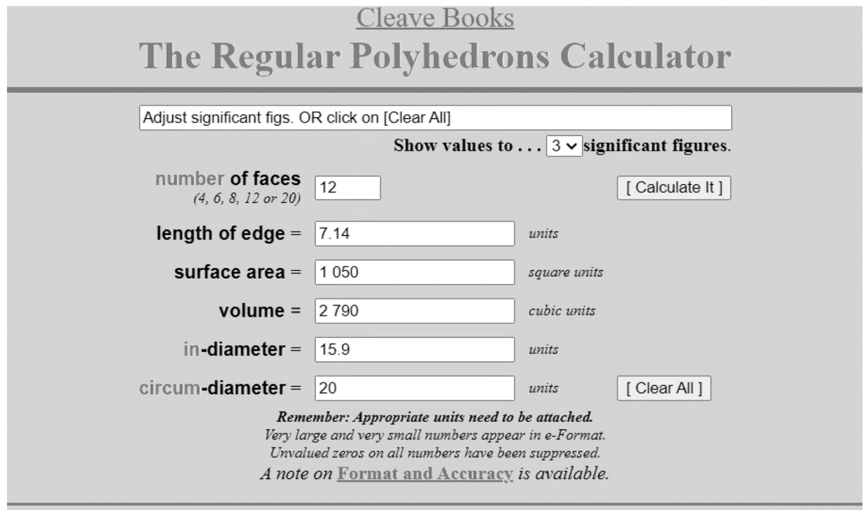
<u>Coffee Stirrer Structures, Soap Film Configurations and the Birth of HyperTiles</u> Robert Becker, [HyperTiles LLC]

A wide range of polyhedral frames can be built with coffee-stirrer straws and plastic-coated twist-ties.



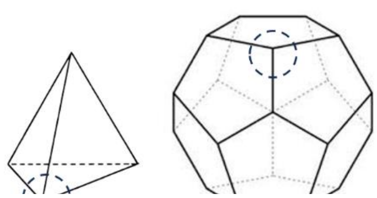
It is important to find a coffee stirrer straw with an internal diameter that can just barely accommodate a folded-over twist-tie, as shown at right. It should take some effort to insert the folded-over twist-tie so that the friction with the inside walls of the straw will keep the assembly together.

These are intended to be temporary structures easily taken apart and reassembled into different structures. If desired, however, they can be made more permanent with the addition of small amounts of glue placed on the twist-tie bend before it is inserted into the coffee stirrer hole. [The author has found that E6000 Premium Contact Adhesive works quite well.]

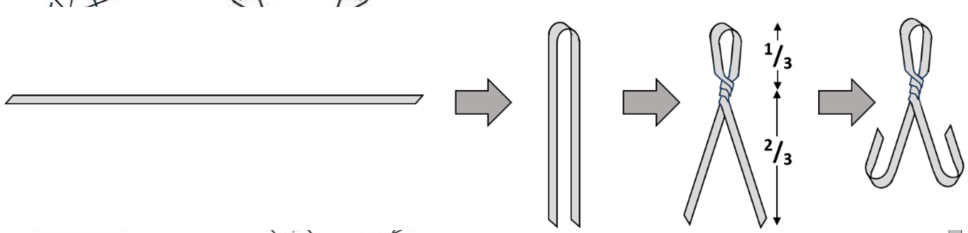


The technique is simple:

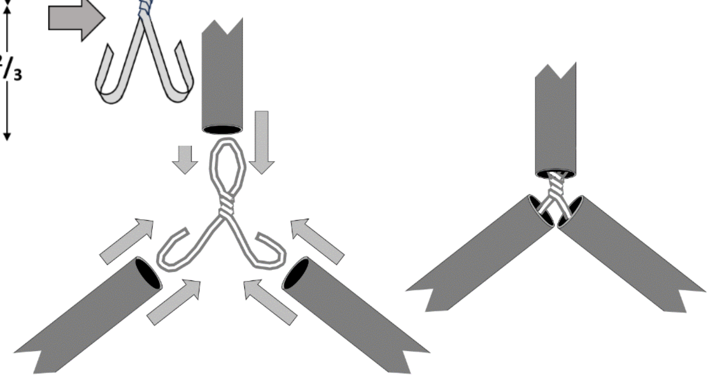
1. The coffee stirrers can be cut down to any desired size. Charts and "calculators" such as this one – that list the dimensions and edge lengths of various geometric solids – are quite common on the internet. So if you want to construct a dodecahedron (12-sided) that is 20 cm in circum-diameter, you will want to cut your each of your coffee stirrers down to 7.14 cm.



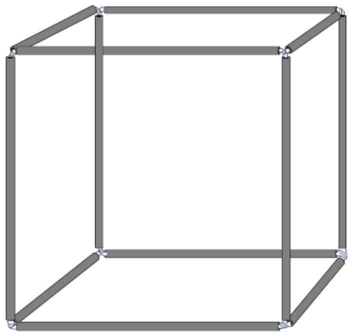
2. To make the twist-tie into a three-way connector (as might be used for the vertex of a tetrahedron, a cube, a truncated octahedron, a dodecahedron…), fold the twist-tie in half. Twist it with 3-4 *tight* twists about one-third of the way from the bend to the loose ends. Then take each of the two loose ends and bend them over.



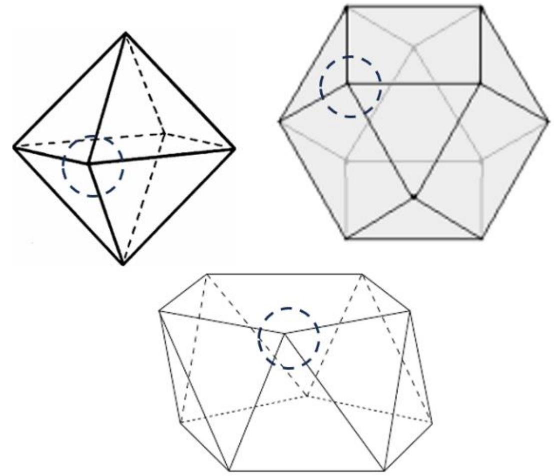
3. These three bent-over extensions can all be pressed flat and then pushed into the open ends of three separate coffee stirrer sections, as shown at far right. The fit should be snug enough to hold the vertex together.



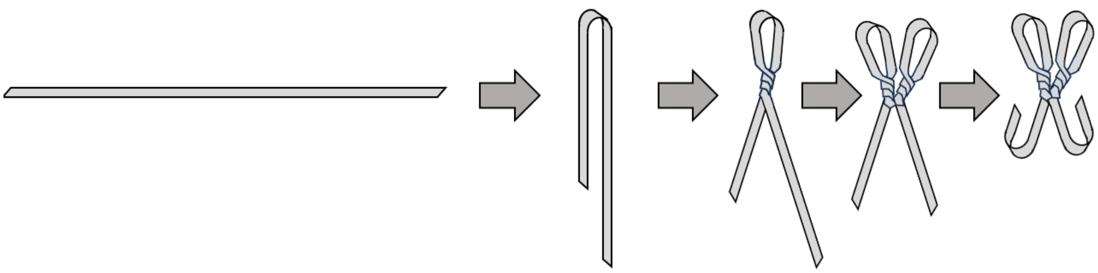
***Those participating in the G4G15 Gift Exchange have received a bag containing 15-20 coffee stirrers (13 cm long), 20-25 twist-ties (10 cm long), one pre-made three-way juncture – like the one shown at right, *and* two sample HyperTiles and two connectors – as described on page 3.**



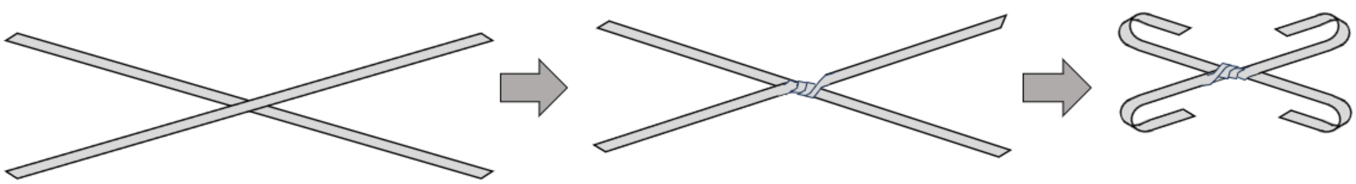
4. This process can then be repeated at each end of the coffee stirrer sections to create the desired shape, like the cube shown at left:



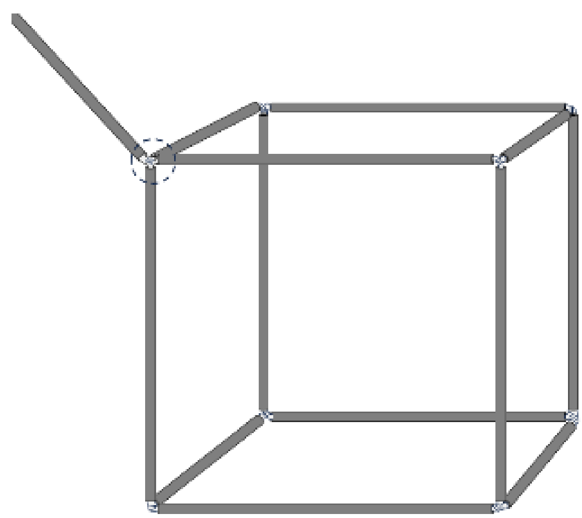
5. To make the twist-tie into a *four*-way connector (as might be used for the vertex of an octahedron, a cuboctahedron, a pentagonal antiprism…), fold the twist-tie in not-quite-half (think 40-60). Twist it with 3-4 *tight* twists about one-third of the way from the bend to the shorter loose end. Then make a second twisted loop using the longer loose end. Then take each of the two loose ends and bend them over.



Or… should one twist-tie prove too short to make this four-way configuration possible, use *two* twist ties. Cross them at their midpoints and then make 4-5 *tight* twists at their intersection. Then take each of the four loose ends and bend them over.



Also, a four-way connector can be used in place of one of the three-way connectors so that a handle can be added to a cube or tetrahedron. This is often quite handy for observing the patterns that form when these polyhedral frames are dipped in soapy water solution.



Speaking of which, dipping such frames in soapy water reveals the minimum surface structures that form on the frames. The soap films solve the problem of how to cover the edges of the frame with the least total surface area. These film configurations are sometimes made up of all flat surfaces, but often they will include hyperbolic surfaces – saddle shapes with negative curvature. The films will never have positive curvature unless the task also includes encapsulating a certain volume of air.

Many amazing explorations can be enjoyed by dipping these frames in soapy water, pulling them out and then popping various portions of the configuration and seeing what new configurations form. (5% Dawn dish detergent in tap water works just fine.) The cube shown above has well over twenty distinct and very beautiful soap film configuration's that can be produced upon it.

When a tetrahedral frame (A, below) is dipped in soapy water, what forms is a collection of six flat triangular films – all meeting at the central point (B). This is the best way to cover all six edges of the tetrahedron (highlighted in yellow) with the least surface area. When the lower righthand film (marked by first X) is popped, the arrangement instantaneously changes to one that involves just three films - one flat film (approximating a minor segment of a circle) and two somewhat hyperbolic films that all meet along a curved (parabolic?) line (C). This is the best way to cover the five tetrahedral edges highlighted in yellow with the least surface area. When the the upper left film (marked by the second X) is then popped, the arrangement immediately changes to a single film that approximates a hyperbolic paraboloid (D). This is the best way to cover the four tetrahedral edges highlighted in yellow with the least surface area. [This video shows this transformation.] This particular hyperbolic shape on a tetrahedral frame is what inspired the author to create a construction toy, HyperTiles (E).

Using just this one simple hyperbolic shape as building block, and a small flexible, hinge-able connector (F), a huge variety of structures can be created with all sorts of surprising mathematical features (G). Many of these are featured at the Gallery of Structures page on the HyperTile website.

Anyone interested in learning more about HyperTiles or possibly purchasing sets should visit the website at https://www.hypertiletoy.com/.