Exercise 3: Hyperbolic Paraboloid: A Mini-Sunshade

Objective:

Learn to fold a model with a different way of compressing paper than the objects in the first two exercises. This object has the characteristic of compressing down to a much smaller area than the original square of paper used, but this model does not fold flat.

Experience the mechanical action of a model that seems to auto-matically arrange itself into the final desired position.

Make a model that has the look and action of the sunshade on the James Webb Space Telescope.

Materials:

- One square of paper. A square made from copy paper works well. Very thin paper does not work particularly well. The paper should have a bit of "body."

Ages: 10 and up

Time Needed: 30 min

Background: Spacecraft

A hyperbolic paraboloid is an infinite surface in three dimensions with hyperbolic and parabolic cross-sections.

In spacecraft like NASA's Chandra X-ray Observatory, sunshades are some of the most important elements of the spacecraft system. For a telescope like Chandra, whose "eyes" are too sensitive for the bright light from our nearest star, blocking the light from the Sun is critical to keep it working properly. Located at the front of the spacecraft where radiation enters the telescope, Chandra's sunshade door remained closed until Chandra achieved pointing control in orbit. Once opened, it shadows the entrance of the telescope to allow it to point as close as 45 degrees to the Sun. The Hubble Space Telescope also has a sunshade door, an aperture door, which not only prevents sunlight from shining down the telescope barrel, but also kept Hubble safe during servicing missions to upgrade the instruments.

However, the sunshade on NASA's James Webb Space Telescope (JWST) is on another level. JWST is a large space-based telescope that will observe infrared light from the Universe. It will study the history of our Universe, from the first glow after the Big Bang, to the formation of solar systems capable of supporting life on planets like Earth, to the evolution of our own Solar System.

A number of innovative technologies have been developed for JWST's spacecraft. These include a primary mirror made of 18 separate segments that unfold and adjust to shape after launch to be about 6.5 m (21.3 ft). The mirrors are made of ultra-lightweight beryllium. But the biggest feature of the JWST is a tennis court sized five-layer shade, or sunshield, (21.197 m x 14.162 m (69.5 ft x 46.5 ft) that attenuates heat from the Sun more than a million times. JWST's sunshield was designed to be folded twelve times in order to fit inside the rocket that will boost it into outer space (4.57 m × 16.19 m).

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For satellites or spacecraft that approach our Sun, a sunshade is typically referred to as a heatshield. NASA's Parker Solar, launched 2018, for example, has gotten closer to the Sun than any human-made object ever has before. Temperatures on the heat shield reach almost 2,500 degrees Fahrenheit, though the spacecraft will be at only 85 degrees Fahrenheit. The heat shield is true thermal protection system. Weighing about 160 pounds, the shield is eight-feet in diameter, can be used to defend the spacecraft against the intense heat and energy of our star. The Sun-facing side of the heat shield is sprayed with a special white coating to reflect as much of the Sun's energy away from the spacecraft as possible.

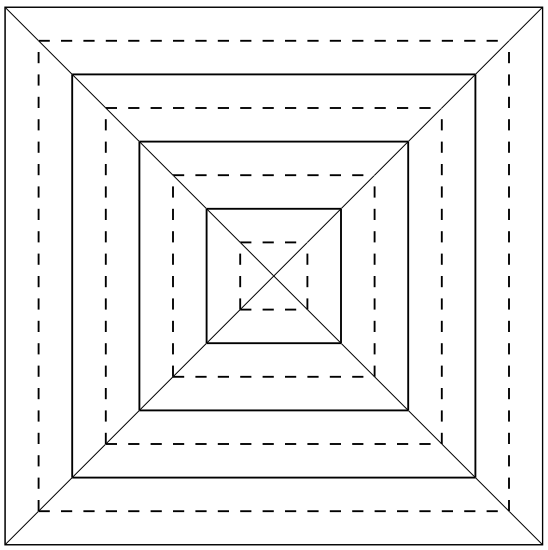
Exercise 3: Hyperbolic Paraboloid: A Mini-Sunshade (cont.)

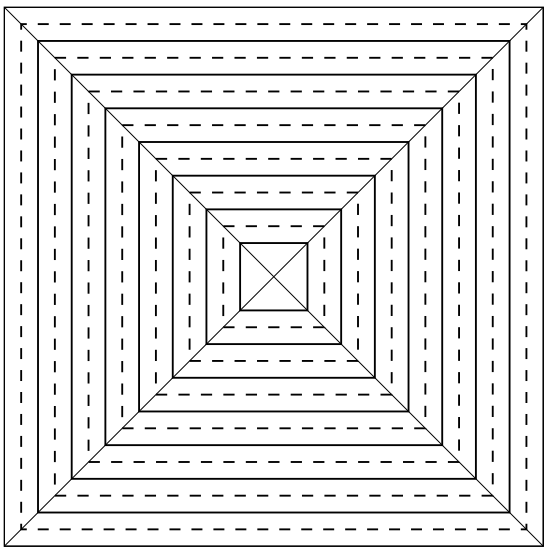
Process:

You will need a square piece of paper for this model. It is fine to make a square from a piece of copy or letter paper.

1. Fold both diagonals into the square.
2. Make folds horizontal to the edge of the paper so that each of the 4 sections is folded into 8 equal parts. Do not fold beyond the diagonals.
3. Reorient the folds so that they alternate between mountains and valleys, in other words, fan fold the creases in each section. Make sure that mountain folds meet other mountain folds at the diagonals, and the same for the valley folds.
4. Refer to the "Hyperbolic Paraboloid" diagram sheet for guidance about the orientation, mountain or valley, of the folds.
5. Gently push in on the 4 sections of fan folds until they collapse flat along the diagonals and into the middle of the square. 2 diagonals will want to point down and the other 2 will want to point up. The model will fold fairly flat, but it will not fold totally flat in the middle.
6. Spread the paper out part way until a saddle shape is formed with 1 set of opposite corners pointing up and the other set of opposite corners pointing down. The fan folds will be partially open and form a "wavy" surface.

A second diagram is provided showing each section divided in 16 equal parts for a more curved, refined look if desired.





Thought Questions:

- Can you observe why this model does not fold flat? What is getting in the way of flat folding?
- If you were to make a box to hold this model, what would the dimensions need to be?
- Can you make something similar to this model from paper that has more sides than a square? For instance, a pentagon? Hexagon? Which polygons work and which do not?
- Art Connection: Can you make an interesting coloring of this model using some of the features of the crease pattern?