Exercise 1: Corrugation: A Mini Solar Array

In origami, a corrugation is a style of design that showcases the entire surface of the paper such that every fold is visible.

Objective:

Show that a simple model that can be folded by a novice folder gives a process for significant compression.

Teach students a method for compact folding. This is a simple four-step origami model that is effective in greatly reducing the area and/or volume of the folding medium. It follows on the conclusions from the introductory exercises about the compact-ability of paper through folding.

Show the relationship between this corrugation and items used in space, such as a solar array. Also, there are similar, but more complex folding methods, such as the Miura-ori folding process.

Materials:

- One piece of copy paper (or something similar) for each student. The paper can be any shape rectangle, including square, but needs to be the same size.
- If old calendar pages are available, they make an interesting look that could be folded for a second model

Ages: 10 and up

Time Needed: 1 hour

Background: Spacecraft

A solar array is a group of solar panels that captures energy from our Sun to generate electricity as a system. Many spacecraft have solar panels to convert sunlight into the electrical power to help run the spacecraft. Solar arrays have a lot of surface area in which to be pointed towards the Sun to gather all the energy needed.

NASA's Chandra X-ray Observatory, for example, travels about a third of the way to the moon at its farthest point from Earth, in order to observe the X-ray Universe. Chandra generates the electrical power needed to function from its solar arrays. The power is then stored in three banks of batteries, and distributed in a carefully regulated manner to its parts. Chandra's two 3-panel solar arrays produce about two kilowatts of power (roughly the same power as a hair dryer!) for the heaters, science instruments, computers, transmitters, etc. on board.

Chandra's arrays were unfolded like an accordion. With its solar arrays deployed, Chandra measures 19.5 meters (64 ft) wide. It's about as long as a school bus, and was the largest spacecraft to ever fit inside the bay of the Space Shuttle. In order to fit inside the Shuttle, Chandra's solar panels had to be folded up, and then unfolded after it was deployed and made its way to its orbit.

Researchers from NASA's Jet Propulsion Laboratory (JPL) have also been designing ways to fold up solar panels into more efficient origami-like packages. As larger solar panels are needed for newer kinds of spacecraft, accordion-style deployment can become riskier, and more liable to fail with each layer of expansion. Creating an origami-packaged solar panel system requires innovation in both the solar array materials and its "packaging," as solar panels can't be made paper thin. As you'll see in the activity below, each fold or bend increases the overall thickness of the object you're making. Engineers have to take such increases into account when creating solar arrays or other expandable parts of a spacecraft.

The following activity will use a corrugation style of folding to create a mini-solar array.

Exercise 1: Corrugation: A Mini Solar Array (cont.)

Process

This model can be folded from any rectangle, including a square. The fan folds can be creased in either direction, short or long (not both).

1. Make creases horizontal to the edge of the paper, dividing the rectangle into eight equal sections. There are many ways to accomplish this goal. One way would be to fold the paper in half & unfold. Fold each of the halves in half. Fold the entire strip in half again, making eight equal sections. Unfold.

2. Fanfold the rectangle, that is, make sure that the creases made above alternate between mountain and valley folds, reversing folds where necessary. Make creases very firm.

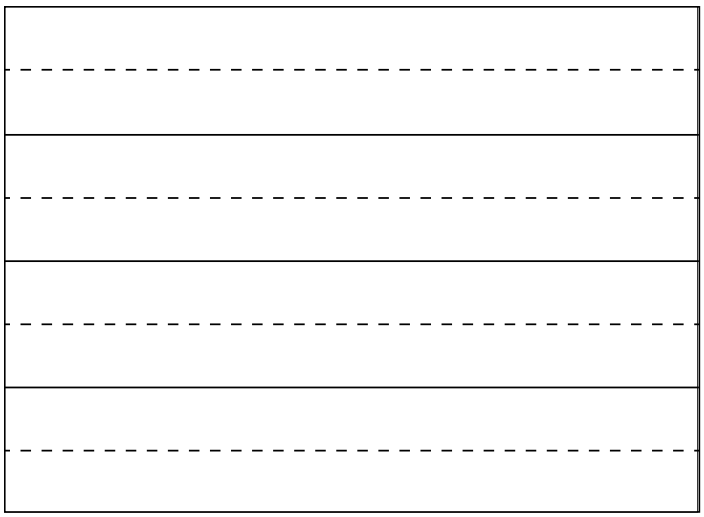
3. Place the folded strip horizontally with the raw edge of the top layer facing away from you.

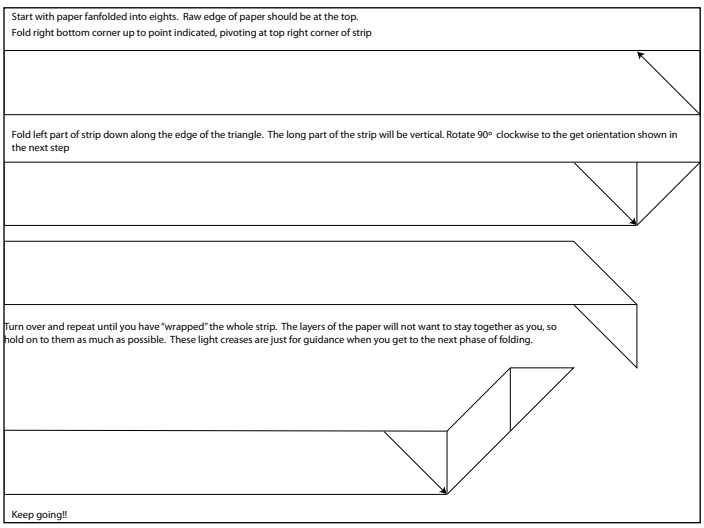
4. Fold up the bottom left corner to lie on the top edge, pivoting at the top right corner. Make sure the crease goes exactly to the top right corner. You should see an isosceles right triangle. Crease as well as possible, given the thickness of the strip.

5. Bring the left, unfolded, portion of the strip down along the edge of triangle folded in the previous step. Now the unfolded portion of the strip will be vertical.

6. Turn the strip over, which will reorient the unfolded portion of the strip to be horizontal.

7. Repeat the previous 3 steps until the end of the strip is reached, trying to keep the strip from spreading apart as much as possible.





Exercise 1: Corrugation: A Mini Solar Array (cont.)

8. Open back to the full rectangle. Orient the first row of V's into mountain folds with short vertical folds inside the V's oriented as valley folds. The rest of the paper remains fan folded and the whole sheet can be collapsed with the V's folded within. Note that there will be a mountain fold coming from the bottom of each V to the bottom of the paper and alternating with valley folds.

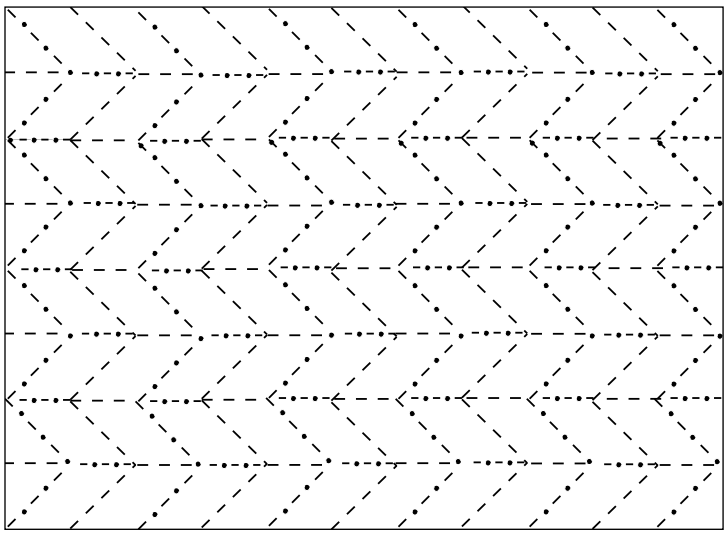
9. Open the rectangle most of the way without flattening it completely. Make sure that the first row of Vs stay creased into the mountain orientation. Turn the rectangle over to the back. The V mountain folds will now be valley folds.

10. Now make the second row of V's into a series of mountain folds. You will also need to reverse each of the fan folds below the V's. It might actually work better to reverse the fan folds first up to the row of V's being worked on, and then encourage the V's into mountain folds.

11. Continue the process of turning the rectangle over, reversing the fan folds below the V's and creasing in a row of mountain folded V's.

12. Refer to the "Chevron Corrugation All Creases" diagram sheet for guidance about the mountain or valley orientation of the folds.

13. When you are finished, you should be able to collapse the rectangle back into a strip with all of the V's sandwiched in between the fan folds.



Thought Questions:

- What is different about the corrugation folding process/result than just fan folding the paper? Is it more effective (i.e., does corrugating decrease the "footprint" of the paper more than just fan folding it)? If so, in what way?
- Can you think of other ways of pleat folding/corrugating paper that would produce a significantly different result?
- Art Connection: Color the model with two colors so that you see only one color when looking at it from the left, and only the other color when looking at it from the right. Can you color it in other interesting ways?