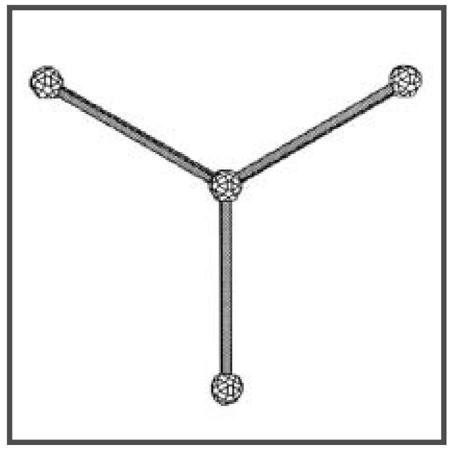
Zome System

Builds Genius!

Bubbles II: Minimal Surfaces

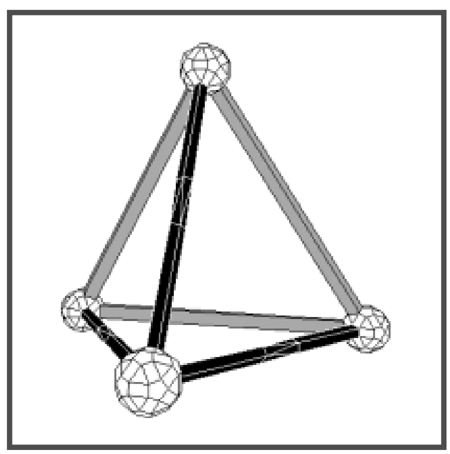
Physics
Intermediate Concept



Lesson Objective:
Students will understand the geometry of soap bubbles joining together, and that the shapes formed by bubbles are derived from laws of surface tension and minimum surface area relationships.

Prerequisite Skills:
Students should have previous experience making bubbles with Zome System frames (“Beginning Bubbles”). Ability to relate symmetry concepts to specific angles and geometric shapes (“Shape and Number,” “What is Reflection Symmetry?” and “Multiple Reflection Symmetry”). Previous experiments and/or discussion about surface tension.

Time Needed:
One or two class periods of 45-60 minutes.



Materials Needed:
- Two Zome System Creator Kits for 25-30 students
- Three or four buckets of water with apx 1/5 cup of liquid dish soap (Dawn works well)
- A few drinking straws
- One balloon (round)
- Two small pulleys and string

Procedure:
Prepare by mixing the bubble solution if you have not saved the solution from the “Beginning Bubbles” class. Place the buckets in your classroom so the students have space to work around them. Place newspapers on the floor and workspace to absorb spills. Initiate the class with a discussion about how natural systems are affected, if not driven by, least energy considerations. *Can the class think of a good example?* One example is a river. It will always follow the path of least energy to the sea. It can’t go up and over a mountain when it can

go around. This is not laziness, it is simply a consequence of natural law whereby nature expends the least energy possible.

The soap bubble is another good example of this. *What shape are most soap bubbles? Why is it shaped like a sphere?* Allow some discussion on this topic.

A balloon, which works according to the same principles as a bubble, can be used as a representation of the soap bubble. As you blow up the balloon, the surface tension increases, the skin of the balloon becomes tighter, pulling away from itself in every direction on the sphere. As with bubbles, if the skin becomes too thin, the balloon will pop. The bubble is at the equilibrium point between the surface tension of the soap film (pulling inward) and the interior air pressure (pushing outward).

So, why are the bubbles in the shape of a sphere? Why not a cube or a pyramid? The bubble wants to have the least surface area on the outside with the most interior volume for the entrapped air. The shape with the highest volume with the least surface area is the sphere. It is also symmetrical from every possible direction, demonstrating the equal pressure and tension on the bubble.

Where else do we see this balance of internal and external forces?

When bubbles join they are trying to pull equally on each other even if they are different sizes. The teacher can use an easily pre-made apparatus, consisting of two small pulleys and string, to explain. Tie a weight to a weight of some kind. Then tie two other strings to the end of the string holding the weight. Run the two strings over the pulleys.

No matter how we move the pulleys around, the strings continuously adjust their position to maintain 120° angles between them. Soap bubbles do this too; when a change is made, either the addition or popping of a bubble, the whole cluster rearranges until equilibrium is reached. The students can use 3 blue Zome System struts at 120° angles to check the angle of the strings.

Next, have each student draw six sets of dots in a triangle as shown. Challenge the class to find the shortest path connecting the three dots. They can measure the total path and compare them. *Which is the shortest path?* Try the same test with four and five dots. *What do all the shortest paths have in common* (three way corners)*?*

Complete the class by letting students continue their exploration of bubbles with the aid of Zome System structures. Allow them to build simple 3-dimensional structures and dip them in the bubble solution. Circulate and assist the teams as necessary, while calling attention to discoveries made by the students. *Why do the bubbles not stay on the outside of the frame* (the bubble films that join inside the structures are smaller than those on the outside)*? How does this relate to the balloon? How do the bubble films join together in the frames* (each line in the bubble shape is created by three films meeting at exactly 120°*?* Discuss how the bubble lines in a tetrahedron or a triangular prism represent the shortest distance between the nodes in the structure. *What is a practical application of this kind of knowledge* (a good example is a cable company looking for the most economical way to connect a number of cities)*? Why do the lines not meet in the center of a cube or a pentagonal prism* (there would be too many bubble films meeting in one point)*?*

<u>Assessment</u>:

Review notes in student journals, and ask team representatives to present ask the group's findings. Students will have met the standards if they can verbalize how bubbles exemplify minimum energy use in nature. To exceed the standards they must be able to define how the least energy principle is modified by the natural 3-fold symmetry of the bubble.

Standards Addressed:
* Science standards addressing consistency of natural laws, particularly benchmarks on surface tension and energy use in nature.

Transfer Possibilities:
Physics classes dealing with surface tension, and minimum energy use in nature. Mathematics classes using geometry to address building economics.