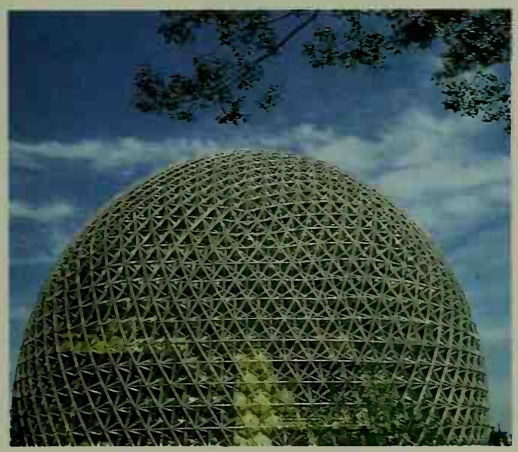
3. The program uses discs that extend outside the sphere, so it yields approximations greater than the actual volume. To use discs that are inside the sphere, replace line 40 with: `LET Y = I * (10/N)`

a. RUN the new program for `N = 100`.

b. Find the average of the result in part (a) and the result in Exercise 2, part (c). Is the average close to the actual volume of the sphere?

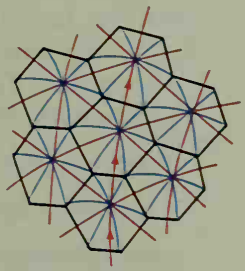
Application — *Geodesic Domes*



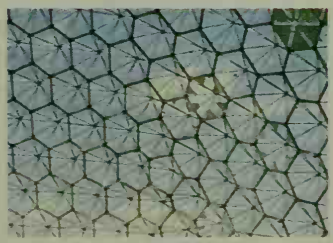
A spherical dome is an efficient way of enclosing space, since a sphere holds a greater volume than any other container with the same surface area. (See Calculator Exercise 2 on page 503.) In 1947, R. Buckminster Fuller patented the *geodesic dome*, a framework made by joining straight pieces of steel or aluminum tubing in a network of triangles. A thin cover of aluminum or plastic is then attached to the tubing.

The segments forming the network are of various lengths, but the vertices are all equidistant from the center of the dome, so that they lie on a sphere. When we follow a chain of segments around the dome, we find that they approximate a circle on this sphere, often a great circle. It is this property that gives the dome design its name: A *geodesic* on any surface is a path of minimum length between two points on the surface, and on a sphere these shortest paths are arcs of great circles.

Though the geodesic dome is very light and has no internal supports, it is very strong, and standardized parts make construction of the dome relatively easy. Domes have been used with success for theaters, exhibition halls, sports arenas, and greenhouses.



The United States Pavilion that Fuller designed for Expo '67 in Montreal uses two domes linked together. The design of this structure is illustrated at the right. The red triangular network is the outer dome, the black hexagons form the inner dome, and the blue segments represent the trusses that tie the two domes together. The arrows mark one of the many chains of segments that form arcs of circles on the dome. You can see all of these features of the structure in the photograph at the right, which shows a view from inside the dome.



Although a grid of hexagons will interlock nicely to cover the plane, they cannot interlock to cover a sphere unless twelve of the hexagons are changed to pentagons. (The reason for this is given in the exercises on the next page.)