

## Kinetic Designs

Roger's Connection enables you to build kinetic designs with freely moving parts. This is achieved by using a simple type of magnetic bearing to suspend smaller spinning designs inside larger structures. The friction of these bearings is so low, that it is primarily air resistance that finally brings the spinning designs to a stop, often after many minutes.

### The Importance of North and South Ends of the Rods

As mentioned earlier in the section "An Important Roger's Connection secret - North and South," each magnetic rod has a North end and a South end. The North ends attract other South ends and repel other North ends. When building magnetically suspended designs, you must create connections that are "polarized." This is done by attaching all North or all South ends of the rods to a particular ball. It doesn't matter if all North or all South ends are used, only that the rod ends are all of the same magnetic pole. When connecting rods to determine their polarity, it is easy to tell when two rods are aligned magnetically in the same direction because they will attract each other as shown in the compass picture below.

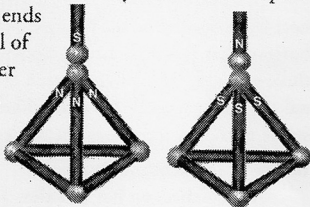
### Build Your Own Compass

Connect two rods together as shown in "Combining Rods for Greater Length." Separate the rods while maintaining their orientation, and add ball-1 between them. Add a new rod to ball-1, at right angles to the first two rods. Connect ball-2 to the other end of the new rod. Connect ball-3 to a new rod, and magnetically pick up ball-2 with ball-3. If it doesn't stick, reverse the orientation of the last rod. Hold up the compass so it can spin freely. When it stops spinning, one of the bottom rod ends will be pointing North and is the North pole of that rod. The geographic North Pole of the Earth is a magnetic South pole (actually located off the east coast of Greenland). Use the compass away from magnets, iron, and steel.

### A Simple Spinning Design

Here is a simple example of a magnetically suspended tetrahedron that will start you on your way in the world of kinetic Roger's Connection designs. Make sure that you have read the sections on "North and South."

1. Build a tetrahedron starting with a triangle (see instructions "Building the Tetrahedron Starting with a Triangle"). The North/South polarities in the triangular base are not important. When you make the tripod however, make sure that the three rod ends that are connected to the top ball are all of the same polarity. It doesn't matter whether they are all North or all South but it is very important that they are all the same. When connecting the triangle and the tripod, keep the magnetically polarized ball of the tripod on top, pointing up.



Either one of these will work, you don't really need to know which is true North or South.

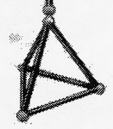
2. Take a new rod with a ball on each end and test which ball end attracts the top ball of the tetrahedron. Pick up the tetrahedron by touching that ball of the new rod to the top ball of the tetrahedron and lift. Try picking up the tetrahedron with the rod and ball by touching it to a different ball on the tetrahedron. You will find that the usually mixed combination of north and south poles on the other balls will result in a weak (if any) connection.

3. Spin the suspended tetrahedron. Congratulations! You have just constructed your first magnetic bearing!

4. You can now attach another rod to the rod you are holding and then another ball to the end of it. Turn the new rod 90° and lay it on the edge of a table so that the tetrahedron and the rod attached to it hang over the edge.

The spinning design is now self-supporting.

There are many other kinds of magnetic bearings, usually much more complicated, that are used in science and industry. They often use superconducting electromagnets or electromagnets that are controlled by special electronic circuits. Such magnetic bearings often bear great mechanical loads, and permit high speeds of rotation. Though the magnetic bearing that you have made here is simple by comparison, it is fairly strong, and demonstrates a very low-friction moving connection.



To see the importance of the bearing, remove the bearing ball and connect the tube above it directly to the tetrahedron and see how long the tetrahedron will spin.

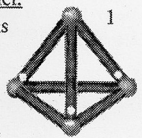
When your spinning tetrahedron finally slows to a stop after many minutes, it will primarily be due to air resistance against the rods and balls, and not from the tiny amount of friction between the two touching balls in the magnetic bearing. Another small influence that tends to slow the tetrahedron is the tiny electrical currents that are induced in the top fixed ball by the moving magnets below. These tiny currents create heat due to electrical resistance which dissipates energy. There are many subtle phenomena occurring in this simple arrangement!

### A Larger Table-Top Spinning Design

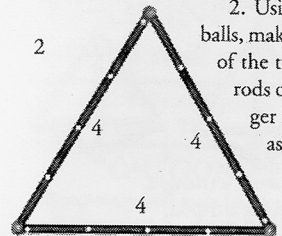
The last design required that you hold it up or hang it over the edge of a table. That's a nice beginning, but here is a fancier one to try. In this design you will be suspending your small spinning tetrahedron inside of a much larger one. The long rods of the large tetrahedron are made from several individual rods connected together as described in the section "Combining Rods for Greater Length." The same principles described in the previous section for the hand-held design are applied here.

Note that the rods in the following illustrations have a dot at one of their ends. We will call this end of the rod the "dot end" for easy reference. This dot shows the polarity of the rods. It doesn't matter whether the dot ends are North or South, only that they are all the same as one another.

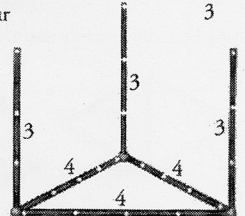
1. Build the small tetrahedron described in the previous section, "A Simple Spinning Design." Make the polarities such that the dot end is away from the topmost ball.



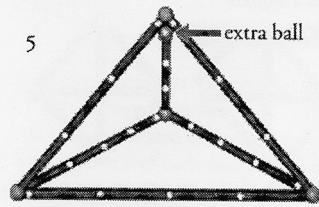
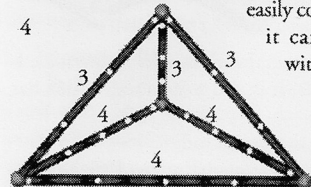
2. Using twelve rods and three balls, make a triangular base. Each side of the triangle is made of long combined rods of four rods apiece. The triangle will be stronger if the polarities are aligned all the way around as shown.



3. Using nine rods, make three combined rods, three rods apiece. Attach each of these rods to a separate ball on the big triangular base, keeping the dot ends pointing up. Although the illustration at right shows the new sections standing up, you may leave them lying flat on your work surface until you are ready to connect their other ends in the next step.



4. Connect the free ends of the three long rods with a new ball. It's tricky holding this all together because the long combined rods are easily collapsed, but it can be done, with care.



5. Do not attach the small tetrahedron yet! First, connect an additional ball to the bottom of the ball at the top of the large tetrahedron to provide more clearance for the small tetrahedron. Also, check that all the rods in the large tetrahedron are well aligned, and centered with respect to one another. This will assure that they don't collapse when the extra weight of the small tetrahedron is added.

6. Attach the polarized top ball of the small tetrahedron to the extra ball you just connected in step 5 above. This step is extra-delicate, as the weight can cause the sides to buckle.

7. Give the small tetrahedron a gentle spin from the bottom, and watch it go! In this step, extra care is required to keep the structure from collapsing, so be gentle. It's fun to see how fast the small tetrahedron will spin. The trick is to apply enough force to achieve good speed, but not so much that the entire structure collapses from the initial push. Good luck!

