



# 3D Flexagon

## Assembly Instructions

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Version 1.0 February 2026



These instructions show how to make a 3D flexagon fidget toy, inspired by Martin Gardner's well-known hexaflexagons, which he first explored in his Mathematical Games column in the December 1956 issue of Scientific American. The design of this object is not mine. However, the approach may be new, since it is intended to be very accessible by using everyday household materials.

### Materials needed

- 12 standard paper clips (either #1 or Jumbo will work)
- 1 small hollow plastic straw (cocktail straw or coffee stirrer)
- Diagonal cutting pliers to cut wire
- Scissors or exacto knife to cut cocktail straw
- Ruler with metric scale in mm
- Needle nose pliers for bending (optional)
- Bending jig (optional, see below)

### Note on G4G Kits

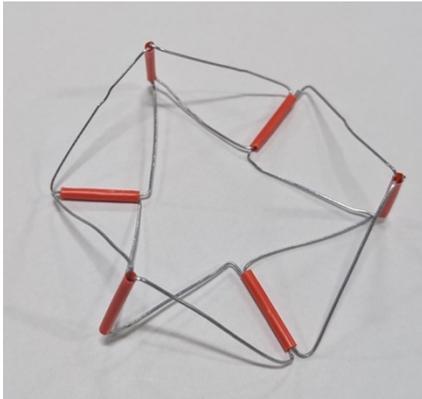
Kits provided in the Gathering for Gardner 16 (G4G16) gift exchange should have necessary wires and straw segments pre-measured and pre-cut, so you can skip steps 1 and 2 below. These kits also have unbent paper clips and a full straw for you to make a second 3D flexagon!

### Note on Bending Jigs

It is easiest to bend the wire with a simple jig.

- **Option 1: 3D printed jig.** If you have access to a 3D printer, here is a link to an STL file that may help with bending. It is a simple wedge with a 22 mm square side, and both a 60° and 90° angle. It also has a small groove for holding the wire along the faces.
- **Option 2: 22 mm wide piece of wood.** If you have access to a table saw and are comfortable with making precise cuts, cut a small board which is 22 mm wide. You can use this for bending the ends of the wires.

Here is a photo of the finished assembly



**Note 1:** There are four wires going into each straw, two from each direction.

**Note 2:** In this orientation, the wires with right angles (see figure 2) end up making a large equilateral triangle where each side has two wire segments that are “horizontal” with straws pointing outward. The wires with  $\sim 60^\circ$  angles connect the “vertical” straws to the “horizontal” straws in an “up and down” pattern.

[Click here for a video of the assembly process.](#)

Figure 1: Finished 3D Flexagon

### 3D Flexagon Construction

#### Step 1: Cut the wires

Unbend the paper clips to create 12 wires that are more or less straight. Cut 6 of these wires to length 95 mm and 6 of them to length 85 mm.

#### Step 2. Cut the straw

Cut the straw into 22mm segments. You will need 6 of them.

#### Step 3: Bending the 85 mm segments

Start by bending a  $90^\circ$  angle in the 85 mm wires, with 22mm on side of the angle. On the other end of the same wire, bend another  $90^\circ$  angle *which is in a different plane*. Do this two more times for a total 3 wires. Repeat the process for the other three 85 mm wires, but this time bend the  $90^\circ$  angle *in the opposite direction (e.g. down instead of up)*. You should end up with 6 zigzag wires, which we call 90R and 90L as shown in figure 2.

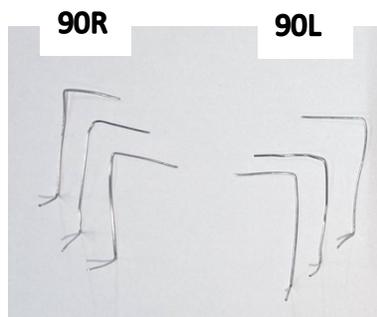


Figure 2: 85 mm wires bent into non-planar  $90^\circ$  angles, with 22 mm ends

**Step 4: Bending the 95 mm segments**

Repeat step 3 with the 95 mm wires. Once the 95 mm wires have been bent at 90° angles, continue bending to decrease each angle to 60° as show in Figure 3. We will call these 6 zigzag wires 60L and 60R.

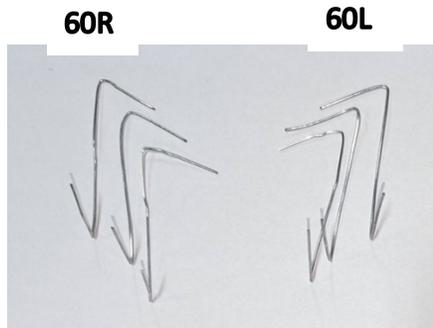


Figure 3: 95 mm wires bent into non-planar 60° angles, with 22 mm ends

Note that there is a temptation, when making the two 90° bends in different planes, to start with both 90° bends in the same plane, and then twist one of them orthogonally out of the plane. Unfortunately, this twisting can significantly weaken or even break the thin 20 gauge wires that we are using. Instead we suggest bending the first 90° bend with a 22 mm side, and then rotate the wire to bend the second 22 mm side on the other end in an orthogonal plane.

**Step 5: Assembly**

For clarity, lay out each wire segment on a sheet of paper, and label areas on the paper to make it easier to identify the different wires. Start with a 60L and 90L wire and two tubes to make a **basic shape**, as shown in Figure 4. Note that, in this orientation, there is a “vertical” straw and a “horizontal” straw.

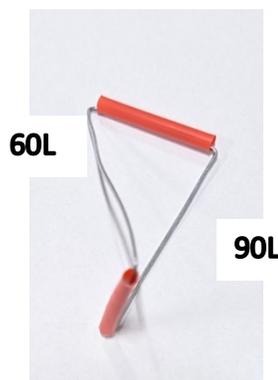


Figure 4: Basic shape using two tubes and a 60L, 90L segment.

Add a 60R segment and a 90R segment with a third tube to create a **basic double shape**, as shown in Figure 5.

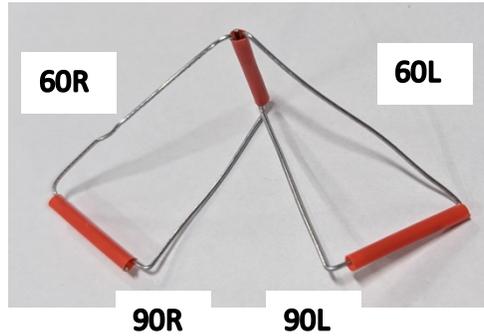


Figure 5: Basic double shape using 60L, 90L, 60R and 90R segments.

Now continue the pattern by adding a 90R and 60R wire to the 90L and 60L side of the basic double shape, see Figure 6. This introduces a second “vertical” straw.

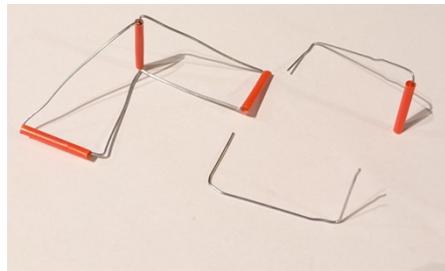


Figure 6: Adding 60R and 90R segments to the 90L and 60L side of the basic shape.

Continuing the pattern, add a 90L and 60L wire, see Figure 7. You should now see one side of the large triangle mentioned in note 2 above in the center segments.

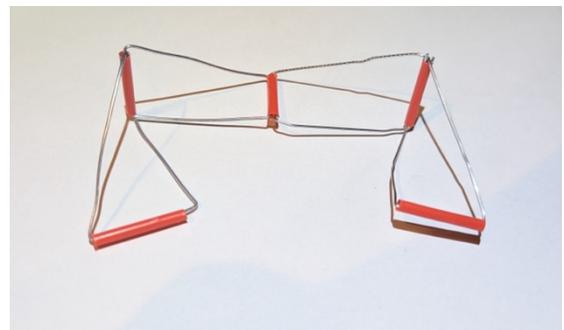
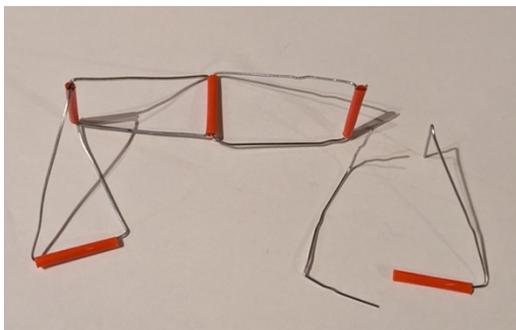


Figure 7: Continuing clockwise, adding 90L and 60L wires (left image). After attached (right image).

Almost done! Take the remaining tube and the remaining 60L and 60R wires and connect them to each other with the final “vertical” tube as shown in Figure 8. Then complete the flexagon with the two remaining 90L and 90R wires, making sure each tube has four wires in it, with two entering from either end, as shown in Figure 8. The finished 3D Flexagon is shown in Figure 1.

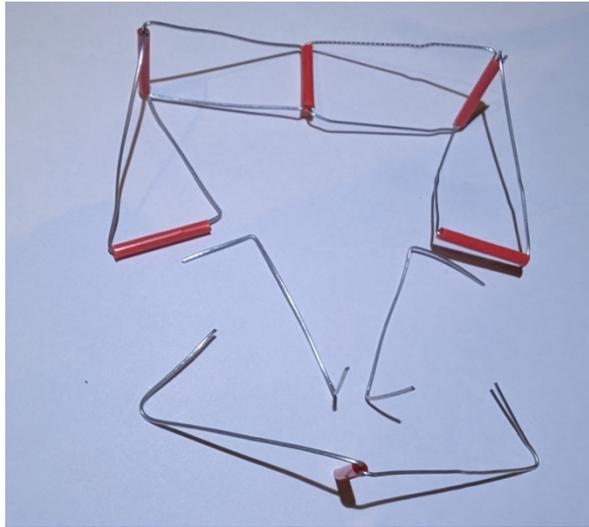


Figure 8: Connect the 60L and 60R wires with the final tube, and attach to complete the flexagon.

## **Good Job! Time to Flex.**

When the flexagon is fully assembled, it’s time to flex! Flex by repeatedly pulling horizontal segments into a vertical position. How many distinct configurations can you see?

Depending on how the wire was cut and bent, the Flexagon may need be adjusted by making small bends in the wire to loosen or tighten angles. You may also remove and trim the ends of the wire if necessary.