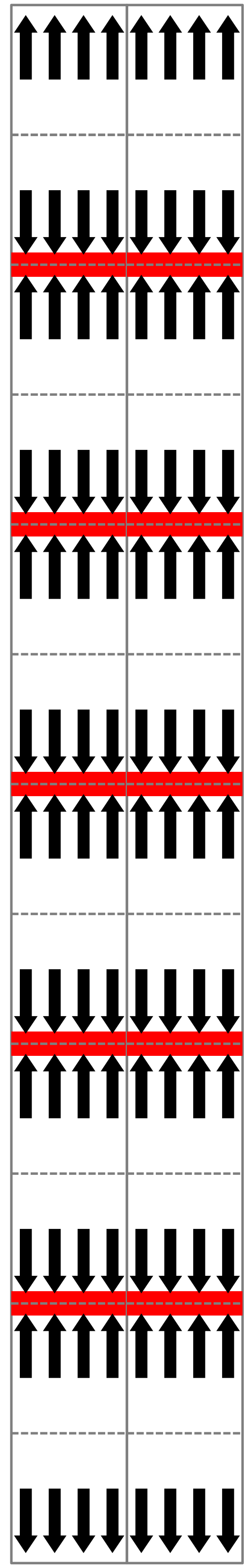
Paper Springs as Demonstrations of Chiral Objects and Circular Polarization

by Dean Campbell, Bradley University, 2011

NOTE: This is a double-sided copy. You need both sides in the correct orientation to build this structure. The page numbers should be above each other.



Interleaving two folded strips of paper produces a springy structure. Grade school children often construct them as part of art projects. These paper springs, like conventional wire springs, have chirality or "handedness" – that is, they have non-superimposable mirror images. Whether a paper spring turns clockwise or counter clockwise depends upon the initial arrangement of the two paper strips before they are folded and interleaved. Figure 1 shows two strips of paper: one green , one yellow. When the yellow strip oriented clockwise to the green strip is placed ABOVE the green strip, the paper spring twists clockwise. When the yellow strip oriented clockwise to the green strip is placed BELOW the green strip, the paper spring twists counterclockwise. Some forms of carbon nanotubes and many biomolecules such as DNA have long, chiral structures.

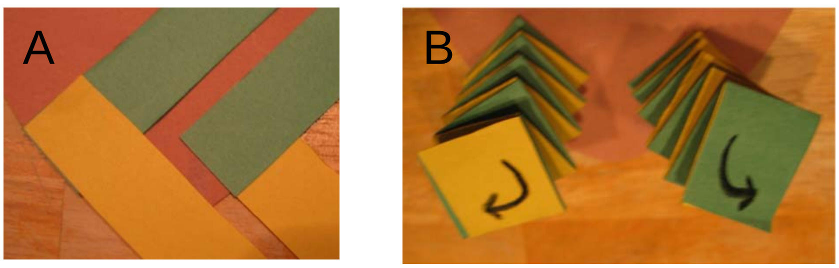
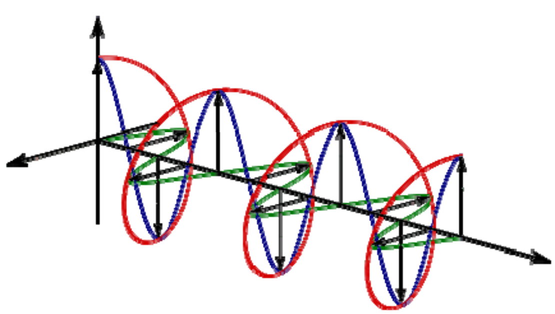
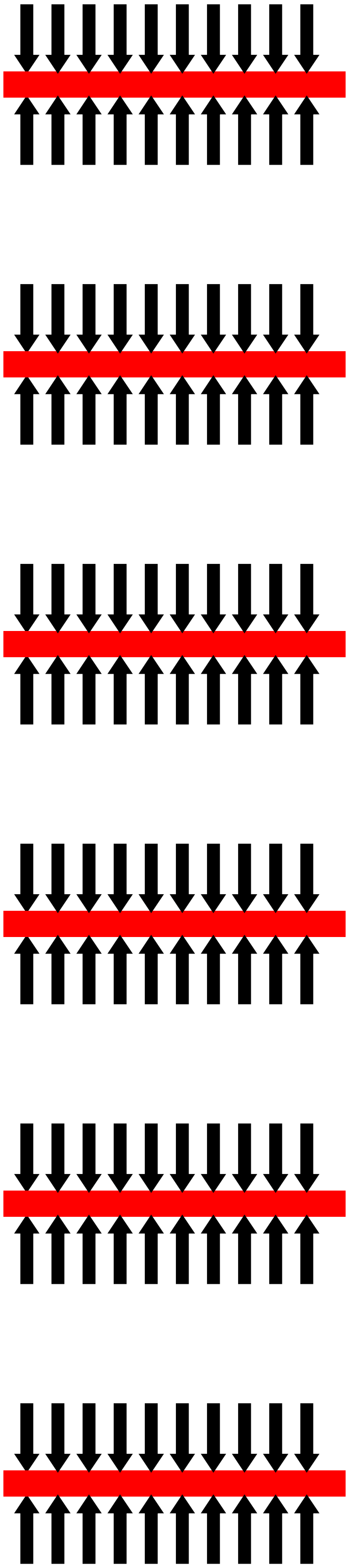


Figure 1 - When the yellow strip oriented clockwise to the green strip is placed ABOVE the green strip (A, left), the paper spring twists clockwise (B, left). When the yellow strip oriented clockwise to the green strip is placed BELOW the green strip (A, right), the paper spring twists counterclockwise (B, right).

In addition to being chiral objects in the their own right, these paper springs can serve as an illustration of circularly polarized light. This sort of light has a polarization or electric field vector that rotates in a circle as the light passes through a point in space. One way to think about how to produce this light is to superimpose to light waves of the same wavelength, each polarized at 90^{O} to each other and offset from each other by a quarter wavelength. Whether one wave is offset in front of or behind the other dictates which way the resulting light polarization will rotate. Figure 2 shows an example of circularly polarized light produced by adding two light waves.

Figure 2 - Circularly polarized light produced by adding two light waves (from http://en.wikipedia.org/wiki/Circular_polarization)





You can build a paper spring model of circularly polarized light by cutting out, folding, and interleaving the paper strips at right. After cutting out the two rectangular strips on page 1 along the narrow lines, fold each strip into a zigzag pattern along the dashed lines so that each thick red bar is at the peak of the zigzag (Figure 3). Each strip then represents a light wave with linear polarization. The polarization orientation is represented by the arrows on the paper. When the strips are interleaved, they are oriented at 90^{O} to each other and offset by a quarter wavelength. The resulting paper spring should have thick red bars that wrap around the axis of the structure in a sort of spiral pattern. As you follow the spiral, the arrows representing the light polarization also follow that spiral. You can change the chirality or the handedness of the spiral (and thus the circular polarization) by changing the order in which the interleaving process for the strips is started.

Figure 3 – A) Two zigzag strip representing light waves with linear polarization, oriented at 90^{O} to each other and offset by a quarter wavelength, and the paper spring they produce. B) Interleaving the paper strips. C) Changing the chirality or the handedness of the spiral (and thus the circular polarization) by changing the order in which the interleaving process for the strips is started.