

Physical applications and other real-life examples

The Slinky model

A Slinky is a toy spring made from a coiled wire. It can be modelled as a flexible elastic helix of fixed total wire length. Unlike a helix wrapped around a rigid cylinder, a Slinky can stretch while **preserving its overall wire length and number of turns**.



A Slinky ¹⁴

To obtain a simple mathematical model, we focus on a single turn of the Slinky and assume that it remains approximately a circular helix during stretching.¹⁵ Such a turn is described by a radius r and a vertical parameter c . Its arc length is

$$L_{turn} = 2\pi\sqrt{r^2 + c^2}$$

Assuming that the stretching is distributed uniformly along the Slinky, the length of each turn remains constant. Therefore:

$$r^2 + c^2 = A^2$$

where A is a constant determined by the wire length of one turn.

This relation shows that as a Slinky is stretched:

- c increases, so the turns become more vertically elongated;
- r decreases, so the Slinky becomes narrower.

Geometric interpretation in the $r - c$ plane:

The possible values of r and c satisfy

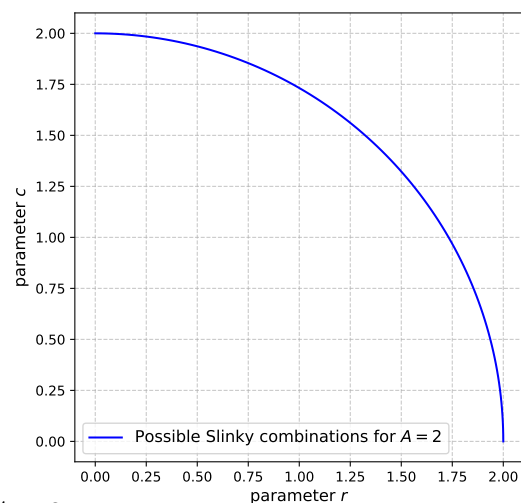
$$r^2 + c^2 = A^2 \quad r \geq 0, \quad c \geq 0$$

so they correspond to the points of a quarter circle of radius A in the $r - c$ plane.

As the Slinky is stretched, the point (r, c) moves along this quarter circle:

r decreases while c increases.

The figure on the right shows all possible pairs (r, c) for a Slinky turn with fixed length parameter $A = 2$.



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¹⁵This is a simplification: a real Slinky does not remain a perfect helix under deformation.

Bolts and nuts

The thread of a bolt forms a helical ridge wrapped around a cylinder. The matching thread inside the nut follows the same helical geometry, allowing the two components to engage.

When the bolt is rotated relative to the nut, these two matching helices interact to convert rotational motion into linear motion.

For a bolt and nut to fit together correctly, their threads must share the same geometric characteristics, most importantly the pitch, radius, and thread profile.



Figure 11: A bolt and nut pairing and a simplified 3D printed model of the situation.¹⁶

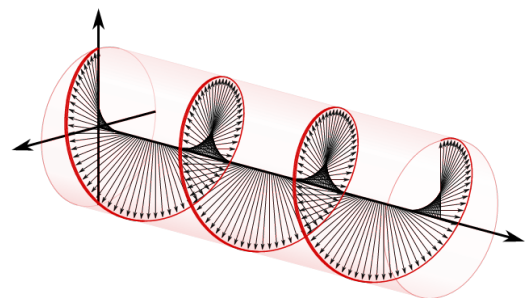
Circularly polarized waves and helical antennas

A helical antenna is an electromagnetic antenna whose conducting element is wound in the form of a helix. When operated in its axial mode, the antenna radiates and receives circularly polarized electromagnetic waves along the helix axis.

This behaviour is closely related to the helical geometry: as the current follows the spiral path, the resulting electric field acquires two orthogonal components with a phase difference of approximately 90° , causing the field vector to rotate during propagation. Efficient axial-mode operation typically occurs when the helix circumference C is of the same order as the wavelength ($C \approx \lambda$)¹⁷, making the geometric parameters of the helix directly relevant to the characteristics of the emitted wave.



Array of four axial-mode helical antenna ¹⁸



Circularly polarized wave ¹⁹

¹⁶CC BY-SA 3.0, https://commons.wikimedia.org/wiki/File:M4_Inbusschraube_focusstacked.jpg

¹⁷John D. Kraus. *Antennas*. McGraw-Hill, 1988. ISBN: 9780071004824, Section 7.1

¹⁸CC BY-SA 3.0, https://commons.wikimedia.org/wiki/File:Traqueur_acquisition.JPG

¹⁹PD, https://commons.wikimedia.org/wiki/File:Circular.Polarization.Circularly.Polarized.Light_Without.Components_Right.Handed.svg

Helices in plants

Plant structures like tendrils and vines often develop helical shapes through differential growth or shrinking between their layers. For example, if the top layer grows faster or the bottom layer shrinks more, the resulting imbalance causes the structure to twist into a helix.²⁰



The tendril of a climber plant.²¹

²⁰Andrej Košmrlj. *Lessons from Biology for Engineering Tiny Devices, Lecture 10-11*. Accessed: 2026-06-19. 2017. URL: https://www.princeton.edu/~akosmrlj/MAE545_S2017/lecture10-11_slides.pdf

²¹CC BY-SA 3.0, https://commons.wikimedia.org/wiki/File:DirkvdM_natural_spiral.jpg