

FRONTLINE

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Demonstrating the vector character of angular momentum using a tandem fidget spinner

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Abstract

Two rotating fidget spinners are mounted in tandem. The two situations where the individual angular momenta of the spinners either add constructively or destructively are demonstrated.

Various setups demonstrating the conservation of angular momentum were popular from the 40s to the 60s and realizations of these can be found in literature [1–5], while more recent experiments utilizing spherical neodymium supermagnets require a minimum set of equipment [6, 7]. Fidget spinners, i.e. hand-held spinning propellers, usually consisting of three plastic blades mounted around a ball bearing, have become popular toys among pre- and elementary-school children. The spinner is held between the thumb and the forefinger while one of the propeller blades is slapped to start the spinning. Two removable pads on either side of the ball bearing provide grips to prevent the hand from touching the rotating blades and to ensure that the spinner can be put down on a surface or shifted from one hand to another. The mechanics of the revolving spinner is rather simple and has already been discussed [8]. The main physical quantities of the revolving spinner are the angular velocity vector $\vec{\omega}$, the moment of inertia I around the main axis passing through the ball bearing, and the angular momentum vector \vec{L} . During a simple non-wobbling spinning around the main axis these quantities are related as

$$\vec{L} = I\vec{\omega}. \quad (1)$$

The vector character of the angular momentum is readily observed if one attempts to wobble the revolving spinner, as the torque $\vec{\tau}$ required to turn \vec{L} , given by Euler's equation

$$\vec{\tau} = \frac{d\vec{L}}{dt}, \quad (2)$$

is provided by the fingers squeezing the supporting pads. The magnitude of the angular momentum $|\vec{L}|$ remains practically constant during the wobble. Thus $\vec{\tau}$ only acts on changing the direction of \vec{L} . A more direct method to demonstrate the vector character of \vec{L} , is to connect two spinners in tandem, figure 1. The two spinners can revolve independently of each other with parallel or antiparallel angular velocities. By gripping one blade of each spinner and quickly pulling away the hand the spinners can be spun in opposite directions with practically equal $|\vec{\omega}|$ s, yielding a zero total angular momentum. Accordingly, practically zero torque is required to wobble the revolving tandem spinner. If, on the other hand, the spinners are spun in the same direction quite a substantial torque is required to wobble the tandem spinner. The difference is immediately felt, showing that the angular momenta of the two propellers should be added as vectors.



Figure 1. The tandem fidget spinner¹. The grip showing how to spin the blades in opposite directions.

By replacing one of the grip pads with a short axle with a sharpened tip the tandem spinner can be used as a spinning top, provided the propellers are spun in the same direction. If they are spun in opposite directions the top will not remain standing on its tip. This can be given as a student challenge. An aluminium axle with a length of 30 mm was used to turn the tandem spinner in figure 1 into a top.

A setup similar to the tandem spinner of two connected bicycle wheels is described in literature [9]. However, fidget spinners are nowadays easily obtained and connecting them in tandem spinner requires only the removal of one grip pad from each spinner and inserting an axle made e.g. PVC plastic through the ball bearings. As our ball bearings had a central hole of 8.00 mm we used a very snugly fitting axle of ~ 8.02 mm.

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