Activity devised by the **AHS PSU Chapter**

GYROSCOPIC WHEEL

AHS STEM Activity: HS Level **Jan 2018**

Why does a helicopter need a tail rotor?

Newton's third law states that every action has an equal and opposite reaction. When a helicopter's main rotor (propeller) spins, the helicopter body will follow this law, and try to spin in the opposite direction! This is what we call torque.

To stop this from happening, we need to find a way to conserve the momentum of the main rotor. This is why we use a tail rotor, which works to fight against torque. This is why, in many Hollywood movies, when the tail is destroyed, the helicopter spirals out of control.[1]

The Demo

Someone stands on a rotating platform. When they spin the bicycle wheel and turn it sideways, they also spins around. What's going on? [2]

Quick Physics

Conservation of Angular Momentum means that the person turns in the opposite direction from the spinning bicycle wheel.[2]

Rotating platform and bicycle wheel

Required:

- Rotating platform (or rotating chair)
- Bicycle wheel with handles
- A partner

The Details

This illustrates an important conservation law of physics: the conservation of angular momentum or turning motion. Anything that is turning has angular momentum. This is similar to inertia, only in rotational motion. If a wheel is spinning in one direction, it wants to keep turning in that same direction. If it is not turning, it tries to stay still.

To show this, someone stands on a level platform that can spin around. If that person gets on carefully, so they're not turning, no matter now much that person twists and dances, they won't be able to spin all the way around. Next, someone else can push the person holding the spinning wheel so that person starts spinning. Now, no matter how hard that person tries, they won't be able to stop spinning. This is conservation of angular momentum.

In the bicycle wheel gyroscope demonstration, there are two possible turning motions. The platform the person stands on turns like a wheel on its side. Call this horizontal turning motion. The other turning motion is the bicycle wheel the person is holding. Initially it is vertical, as a bicycle wheel normally stands. Call this vertical turning motion.

To begin with, someone spins the bicycle wheel. There is vertical turning motion in the bicycle wheel, but no horizontal turning motion of the platform. Then the person tilts the bicycle wheel to the side, so now there is horizontal turning motion where there wasn't any before. Conservation of angular momentum tries to fix this. The platform starts spinning in the direction opposite that of the bicycle wheel. If you add the backward turning of the platform and the forward turning of the bike wheel together, you get zero. So horizontal motion is the same as when we started: equaling zero or no motion. When the bike wheel is tilted back vertically, the platform stops spinning, as in the beginning.

Rocket ships are stabilized this way. They have little wheels spinning inside called a gyroscope. When the rocket ship turns, the spinning wheels turn the other way and bring the rocket back on course. Football players also put a spin on the football to improve the accuracy of their passes. [2]

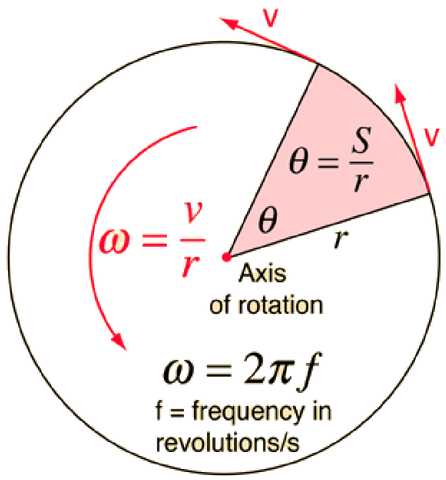
Sources

[1]Smithsonian National Air and Space Museum: http://howthingsfly.si.edu/ask-an-explainer/why-do-helicopters-need-tail-rotor-and-what-torque

[2]The Wonders of Physics - Traveling Outreach Program: https://wonders.physics.wisc.edu/the-bicycle-wheel-gyroscope/

Notes

Angular Velocity



For an object rotating about an axis, every point on the object has the same angular velocity. The tangential velocity of any point is proportional to its distance from the axis of rotation. Angular velocity has the units rad/s.[3]

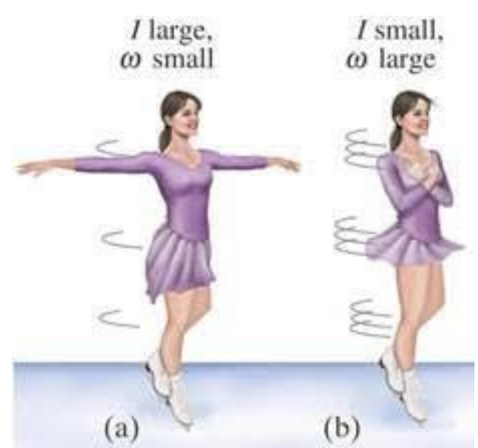
$$v = \omega r \quad or \quad \omega = \frac{v}{r}$$

Sources

[3]HyperPhysics: http://hyperphysics.phy-astr.gsu.edu/hbase/amom.html#am

Examples

Ice Skater



Angular momentum is conserved when no external torque is applied. Since there are no external moments acting on the skater, the angular momentum is the same in (a) and (b). By retracting her arms, the ice skater reduces her moment of inertia by reducing the radius. For angular momentum to stay the same, the angular velocity increases to compensate for the decrease in the moment of inertia.

Helicopter

Because of conservation of angular momentum, when there are no external moments, the sum of the angular momentum of the helicopter will be zero. When the blades of the helicopter spin clockwise, the fuselage (body) of the helicopter will spin in the counterclockwise direction. A spinning tail rotor provides a clockwise moment to counterbalance the fuselage.