Angular Momentum

One of the most interesting and useful concepts in physics is the concept of *angular momentum*.

We already learned about *linear momentum* which is a vector quantity that is conserved in the absence of outside forces and is equal to the *mass* of an object times its *velocity*. You could say that “Linear momentum fights a change in its linear velocity from an outside force.”

Angular momentum is also a conserved vector quantity that remains constant in the absence of an outside *torque*.

You could say that “Angular momentum fights a change in its angular (or rotational) velocity from an outside torque.”

Recall that torque is equal to Fdsinø

Angular momentum is equal to $\omega \cdot I$

ω (pronounced “omega”) is the *angular velocity* of a rotating object and must be measured in radians/second (recall that there are 2π radians in a full circle)

I is called the *moment of inertia* of the rotating object and is analogous to the mass of an object that has linear momentum.

I is a function of the mass of the object and where the mass is placed. An object that has its mass further away from the point of rotation has a larger moment of inertia than an object of equal mass that has its mass located closer to the point of rotation.

Some interesting aspects of angular momentum

- A rotating object is more stable than a non rotating object. A top stays upright as long as it is spinning. (Satellites in space are always kept spinning in order to keep them more stable)

- Bicyles and motorcycles remain upright due to their angular momentum (not because the rider simply has a great sense of balance)

- For an object that is not experiencing an outside torque, as the moment of inertia decreases, its angular velocity increases. Figure skaters use this principle in order to spin faster. After they set themselves rotating, they move their arms and legs closer to the center of their bodies. This decreases their moment of inertia and thus increases their angular velocity and makes them spin faster.

A spring board diver attempting a flip tightens his or her body into as small a space as possible, decreasing their moment of inertia and thus increasing spin rate

• A farm tractor (which must move over large clumps of dirt that would change its velocity) have large heavy tires that have a large moment of inertia. Thus as they move across rough terrain, they stay in a straight line. (On the other hand a racing bicycle with light wheels could not negotiate this terrain)

• 18 wheel trucks have a huge moment of inertia and large angular momentum. Thus the direction of the movement is much more stable than the movement of a lightweight car with light wheels

• Great quarterbacks throw the ball with a tight spiral, giving the ball a large angular momentum, which keeps the ball from fluttering like "a wounded duck."

• Racing bicycles have very light wheels, and designers keep the weight on the outside rim as light as possible (as well as the mass of the tire) in order to minimize the moment of inertia of the wheel. This allows the rider to accelerate more quickly (but reduces the stability of the bike). Trick bicycles solve this problem by having smaller wheels with thicker tires, a compromise that maximizes acceleration and stability.

• Motorcycle riders actually turn the steering wheel to the right when they want the bike to go left. This is very apparent if you watch dirt bike racers (the torques exerted by the dirt track on the tires is much less than on pavement). Stunt drivers also do this. In order to make the car spin so that it faces the left, the driver "yanks" the steering wheel towards the right. Next time you watch a car chase in a movie, check this out. This occurs because the moment of inertia of the motorcycle or car is constant and its angular momentum is constant. By turning the wheel one way (and thus changing its angular momentum one way) the total system of the motorcycle spins the other way. (When the the front wheel is suddenly turned to the right, the back of the bike "spins out" or rotates to the right as well, thus causing the bike to point towards the left.) I once tried to explain this concept to my meathead biker buddy after he had several beers. I'd rather try to teach a gorilla quantum mechanics. Although I did not understand this principle when I owned a motorcycle I can tell you that it is one of the greatest joys of riding. You feel like you are steering with your hips. Bikes respond to your body movements much more than cars (but don't get a motorcycle until you are at least 30 because you are an idiot until at least that age).

• Motorcycle daredevils who make large jumps must shift their body weight forwards as they leave the ramp in order to keep the bike from flipping over backwards. When the bike leaves the ramp, the wheels (without the resistance of the ramp) immediately start spinning faster in a forward direction. Conservation of angular momentum then dictates that the *system* of the bike must rotate backwards. By changing the center of mass of the bike/rider system, the riders exert a torque that fights this backwards rotation.

What is the direction of angular velocity and angular momentum? Recall that angular momentum is a *vector* and thus must have a *magnitude* and a *direction*. But what is this direction.

Angular velocity, angular momentum, and torque actually point along the axis of rotation of the spinning object.

To determine this direction use *the right hand rule*,

To determine the direction of the angular velocity and angular momentum of a spinning wheel, place your right hand on the wheel so that your fingers are pointing in the direction the wheel is rotating. Keep your thumb pointed 90° from your fingers. Your thumb will point in the direction of the angular momentum and angular velocity. (Don't try this on a moving truck). Here is a figure I shamelessly stole off the internet.