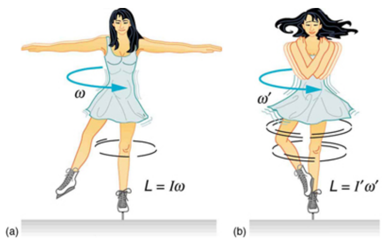
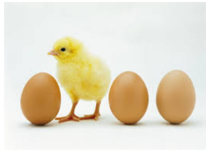
9.6 Angular Momentum



Physics Democracy!
Food for Thought

A hard boiled egg vs. a raw egg: spin comparison.



Which one is cooked? Vote!

Smiley Face	Frowny Face

Why does the hard boiled one stand up?

Answer later!

Angular Momentum (L): Single Mass

The analogue to linear momentum is angular momentum (symbol = L (not length!)).

It equals the product of a moment arm (r) and the linear momentum (p=mv and v=rω) of a particle.

$L = r_\perp p$	L = kg m²/s r = radius (m) p = linear momentum (kg m/s)
$= m r_\perp v$	m = mass (kg) v = linear speed (m/s)
$= m r_\perp^2 \omega$	ω = angular speed (rad/s)

Angular Momentum: System

For a rigid body, angular momentum is:

$L = I\omega$ AP Equation	I = MoI (kg•m²) ω = angular speed (rad/s)

Angular momentum relates to net torque:

$\Delta L = \tau \bullet \Delta t$ AP Equation	τ = torque (m•N) t = time (s)

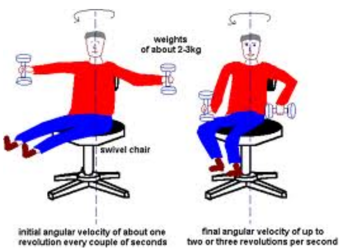
Conservation of Angular Momentum

Like linear momentum, angular momentum is conserved:

$$L_0 = L$$
$$I_0 \omega_0 = I\omega$$

Applications of Angular Momentum

There are many ways that angular momentum plays into daily life - one popular demonstration is a guy rotating on a stool with his arms out.
When he pulls his arms in, he spins faster!



Applications of Angular Momentum

Ice skaters use this when they rotate - by pulling their arms in, they rotate faster, getting even more dizzy!

Her face is a blur!
And look at her weird legs!

Ice Skater Problem 1

A skater spinning at 6 rad/s with her arms tucked in has a moment of inertia of 10 kg•m². The skater extends her arms, resulting in a new moment of inertia of 14 kg•m².
What is her new angular speed?

$$I_0\omega_0 = I\omega$$

$$\omega = \frac{I_0\omega_0}{I}$$

$$= \frac{10\,kg\,m^2 \bullet 6\,rad/s}{14\,kg\,m^2} = 4.3\,rad/s$$

Ice Skater Problem 2

What percent change is her change in angular speed?

$$\% = \frac{difference}{inital} \bullet 100\% = \frac{4.3\,rad/s - 6.0\,rad/s}{6.0\,rad/s} \bullet 100\% = -28.3\%$$

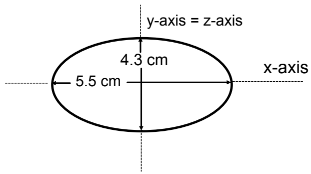
Angular speed decreased by 28.3%.

Eggsample

A 0.065 kg egg is spun starting at 12.0 rad/s on its side. After a few seconds, it stands on end and continues spinning.
Approximating the egg as an ellipsoid, what will the final angular speed be?
Moments of inertia provided:

$$I_y = \frac{m(x^2+z^2)}{5}$$

$$I_x = \frac{m(y^2+z^2)}{5}$$



Eggsample Answer

The egg initially rotates around the y-axis.

Find initial and final moments of inertia, and plug values into the equation:

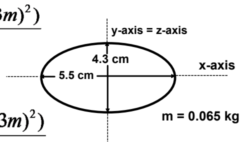
$$I_y\omega_0 = I_x\omega$$

$$I_y = \frac{m(x^2+z^2)}{5} = \frac{0.065\,kg((0.055m)^2+(0.043m)^2)}{5}$$

$$= 6.34E-5\ kg \bullet m^2$$

$$I_x = \frac{m(y^2+z^2)}{5} = \frac{0.065\,kg((0.043m)^2+(0.043m)^2)}{5}$$

$$= 4.81E-5\ kg \bullet m^2$$



Angular Momentum Answer

Then:

$$I_y\omega_0 = I_x\omega$$

$$\omega = \frac{I_y\omega_0}{I_x} = \frac{6.34\ E-5\,kg\bullet m^2 \bullet 12\ rad/s}{4.81\ E-5\,kg\bullet m^2} = 15.8\,rad/s$$

Egg Answer

The hard boiled egg stands because of conservation of angular momentum - the upright egg has a lower moment of inertia, and a correspondingly larger angular speed.

Physics Demo: FAIL

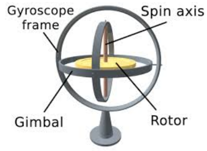
Applications of Angular Momentum

A football has greater stability if it rotates when thrown, so a 'spiral' throw is preferred.

Gyroscopes and tops rely on angular momentum to remain upright as they spin. (Bicycle Wheel Demo.)

They precess around a pivot point, as an external torque (due to the weight force) acts upon them, but they won't fall over until their spin stops (due to friction).

Helicopters rely on angular momentum to fly. They have two rotors for stability.



Homework 9.6

Problems 9.6 in your Booklet
Due: Next Class

Finish Unit 9 Review Scan
Problems: Due SOON!!