Momentum

by

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P3.3d Analyze why seat belts may be more important in autos than in buses.

Items:

1. Linear Momentum.

2. Comparing the Momentum of Two Moving Objects.

3. Angular Momentum .

Linear Momentum (P)

Newton combined mass and velocity to describe the motion of a moving object. He called this expression the object's quantity of motion, or what we call today momentum.   Momentum has the symbol p.

The linear momentum of an object is equal to the product of the object's mass (m) and velocity (v). It is a vector quantity and has the same direction as the velocity. The unit of momentum is kilogram . meter / second (kg.m/s)

Linear Momentum (p)
$$\vec{\mathbf{p}} = m\vec{\mathbf{v}}$$ mass = m, velocity = v Unit: (kg . m/s)

Example 1: A Moving Car

1. What is the momentum of a 1000 kg car moving with a velocity of 15 m/s [E]?

Data Table		
m	P	v
1000 kg	?	15 m/s

$$p = m\,v$$

= (1000 kg)(15 m/s [E])

= 15000 kg.m/s [E]

The momentum of an object is a measure of how hard it is to stop that object.

The momentum of an object depends on both its mass and its velocity. Therefore, combining information about the mass and velocity of an object gives us a way of comparing the motion of objects.

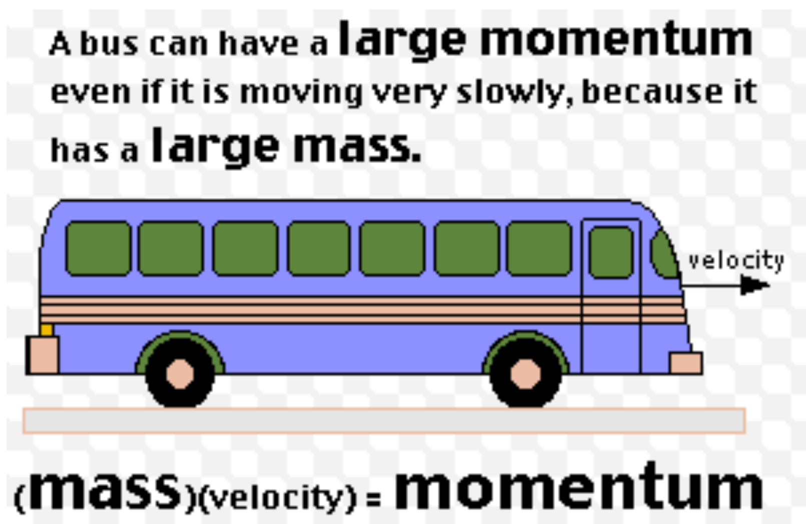
Comparing the momentum of two moving objects

Consider two objects of the same mass, e.g. two baseballs. One of them is coming at you at 10 mph, and the other at 100 mph. which one has the greater momentum? The faster baseball is harder to stop, so it has the greater momentum.

Now consider two objects of different mass with the same velocity, e.g. a Ping-Pong ball and a cannon ball, both coming at you at 25 mph. Which one has the greater momentum? The cannon ball is, of course, harder to stop, so it has the greater momentum.

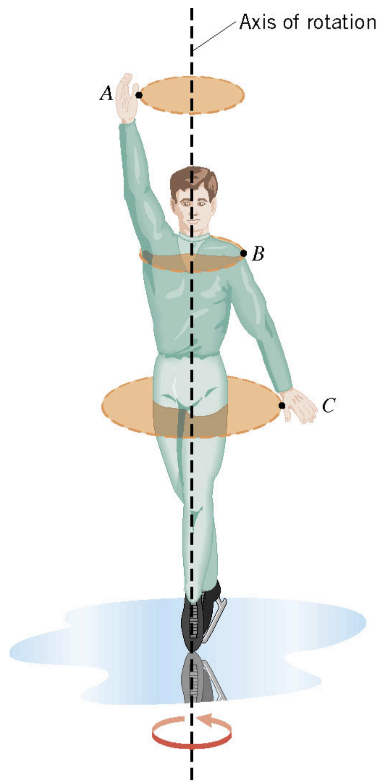
Example 2: Change the Motion of Car or Bus

A school bus and a car traveling at the same same speed would have different amounts of momentum because they have different masses. Because of its large mass, the school bus has more momentum. With his greater momentum, it would be more difficult to change the motion of the bus than to change the motion of the car.



Rotational Motion

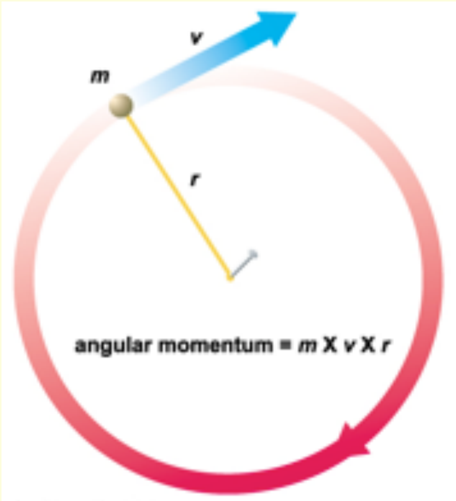
Rotational Motion is the motion of a body turning about an axis called axis of rotation.



In this figure of a skater, all the points of his body such as A, B, and C circulate around the axis of rotation. He is spinning in a rotational motion.

Angular Momentum (L)

Angular Momentum is the momentum involved in spinning/circling. It is the quantity of motion used with objects rotating about a fixed axis. It has the symbol L. It has the unit $kg.m^2/s$.

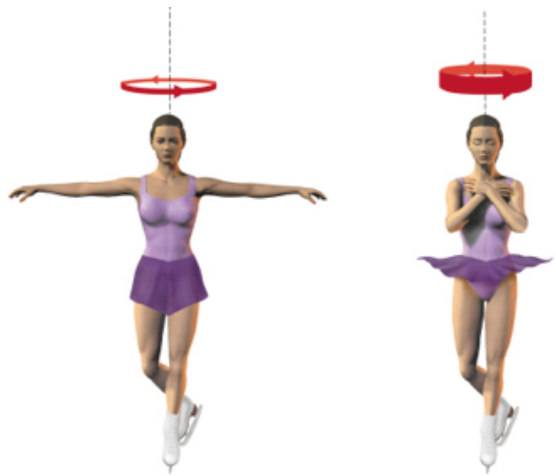
Angular Momentum (L)	
L = mass x velocity x radius = m x v x r Unit: $kg.m^2/s$	

Torque is a turning or twisting force. It is a force that cause a change in the angular momentum of an object.

Conservation of Angular Momentum

The angular momentum of an object changes when a torque acts on the object. If no external force acts on the spinning object, the total angular momentum is constant.

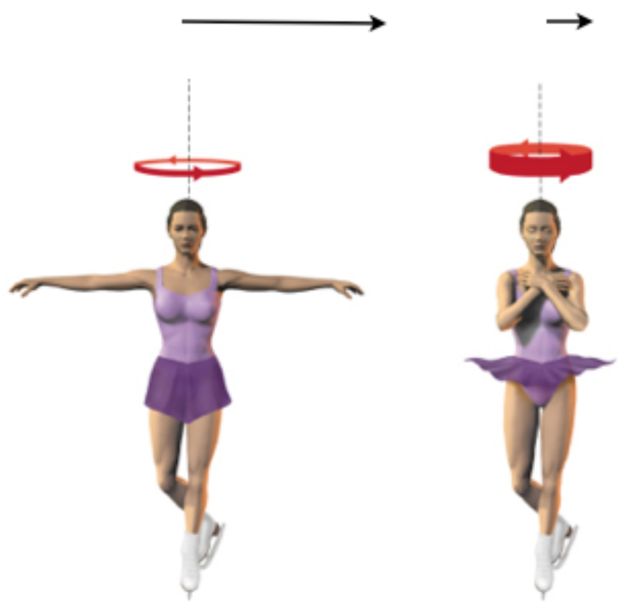
Example 3: *A Spinning Ice Skater:*



(a) (b)

The ice skater is spinning freely with no external force is acting on her. Therefore, her momentum is the same in both situations (a) and (b). $L_{(a)} = L_{(b)}$

The momentum and the mass are constant. The velocity and the radius change.



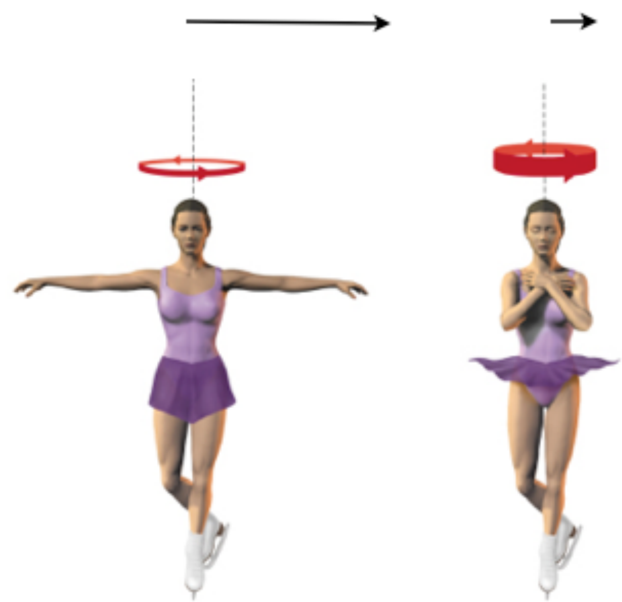
(a) (b)

Radius (r) is shown by the **black arrow** above the skater in situations a and b.

$$L = \text{mass x velocity x radius.}$$

$$L_{(a)} = L_{(b)}$$

In (a) the ice skater opens her arms, so the radius is big (black arrow). The length of the radius is shown by the black arrow starting from the center and extend to the tip of her hand. In this case her rotational velocity is slow.



(a) (b)

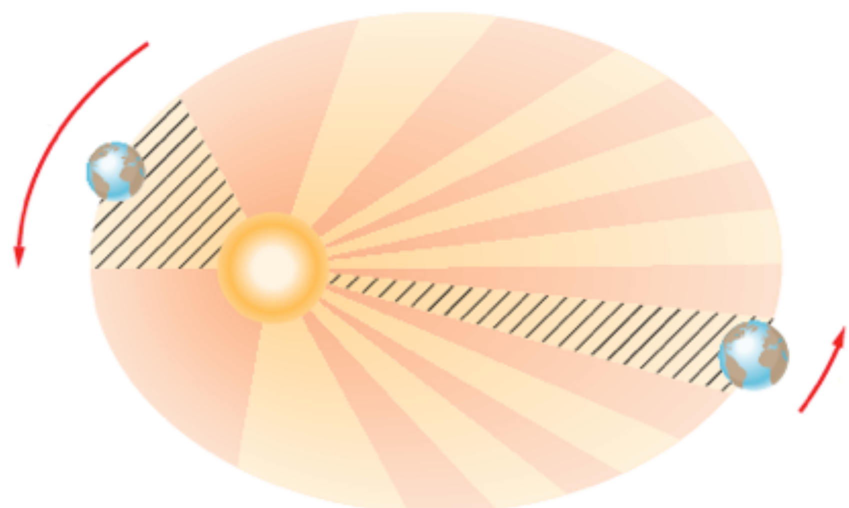
In (b) the ice skater pulls her arms inward, so the radius is smaller (black arrow). Because the momentum and mass are the same, then her rotational velocity increases and she is spinning faster.

Example 4: *A Spinning Ice Skater:*

(a) (b)

Example 5: *Kepler's Second Law:*

An imaginary line from the sun to a planet sweeps out equal areas in equal times. So, the planets move faster when they are closer to the sun and slower when they are farther away from the sun as illustrated in the picture below. The angular momentum of the Earth is conserved during her rotational movement around the sun. The mass of the Earth does not change too.



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2) Cutnell, J. D. & Johnson, K. W. (1998). *Cutnell & Johnson Physics, Fourth Edition*. New York: John Wiley & Sons, Inc.

The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department:"We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

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