Momentum and Impulse

Another Conservation Law…

Momentum and Impulse

I. Momentum and Impulse
   - concepts and definition
   - relation to force

II. Conservation of Momentum
   - internal and external force
   - elasticity

	The student will be able to:	HW:
1	Define and calculate momentum using appropriate SI units.	1
2	Define and calculate impulse and solve problems relating impulse, momentum, and force.	2 – 6
3	State and apply the law of conservation of momentum with proper consideration to internal and external forces.	7 – 9
4	Use conservation of momentum to solve related problems.	10 – 19
5	Define elastic and inelastic collisions and use the definitions to solve related problems.	20 – 26

What is Momentum?

Momentum is the product of mass and velocity.

$$\vec{p} = m\vec{v}$$

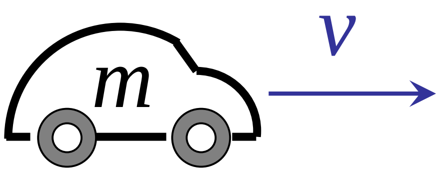
Momentum is a vector that points in the same direction as velocity.

Its magnitude has SI units of: kg m/s

(Note: there is no special defined unit for measuring and quantifying momentum.)

Momentum – Numerical Example

A car of mass 1000 kg is traveling with velocity 20.0 m/s, 0.0º. Find its momentum.



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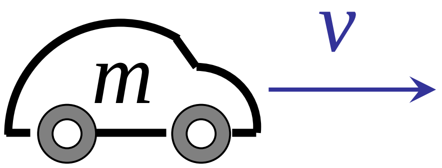

$$\vec{p} = m\vec{v}$$

$$p = (1000\,\mathrm{kg}) \cdot \left(20\,\tfrac{\mathrm{m}}{\mathrm{s}}\right)$$

$$p = 20000\,\frac{\mathrm{kg \cdot m}}{\mathrm{s}}$$

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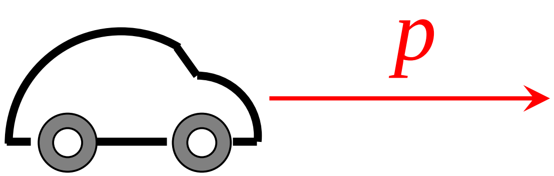

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$$\vec{p} = 20000\,\frac{\text{kg}\cdot\text{m}}{\text{s}},\ 0.0°$$

Momentum is a vector!

Understanding Momentum

245 lbs, 40 yd = 4.9 s

210 lbs, 40 yd = 4.5 s

Whom would you rather tackle –
a tight end or a tailback?

Understanding Momentum

m = 111 kg, v = 7.46 m/s

m = 95.3 kg, v = 8.31 m/s

Which player has more momentum?

Which player has more inertia?

Understanding Momentum

m = 111 kg, v = 7.46 m/s

m = 95.3 kg, v = 8.31 m/s

p = 828 kg m/s

p = 792 kg m/s

More inertia and more momentum!

Understanding Momentum

m = 111 kg, v = 7.46 m/s

m = 95.3 kg, v = ?

At what speed would the tailback have momentum equal to that of the tight end? Would inertia change?

Understanding Momentum

m = 111 kg, v = 7.46 m/s

m = 95.3 kg, v = 8.69 m/s

p = 828 kg m/s

p = 828 kg m/s

Still more inertia

Equal momentum

The greater the momentum of an object the greater the force and time required to stop it.

This leads to the concept of **impulse**…

Impulse is the product of force and time.

$$\vec{J} = \vec{F}\left(\Delta t\right)$$

where: **J** = impulse
F = force
Δt = amount of time that the force acts

Understanding Impulse

A force of 1580 N, 0.0° is required to bring the tailback to a stop in 0.500 s (if he has momentum equal to 790 kg m/s). Find the impulse.

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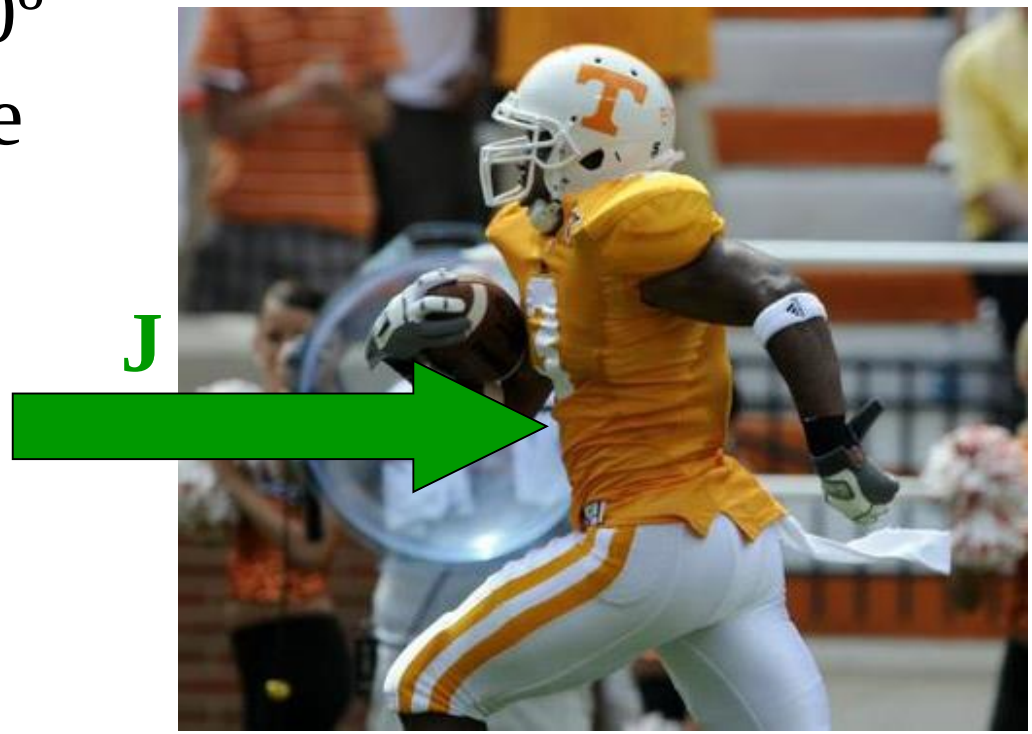

$$\vec{J} = \vec{F}(\Delta t)$$

$$J = (1580\ \text{N}) \cdot (0.5\ \text{s})$$

$$\vec{J} = 790\ \text{N} \cdot \text{s}, 0.0°$$

Would the same impulse stop a player with more momentum?

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Force, Momentum, Impulse

Starting with Newton's 2nd Law it can be shown that net force equals rate of change in momentum…

$$\vec{F}_{net} = \frac{\Delta \vec{p}}{\Delta t}$$

$$\vec{F}_{net}\left(\Delta t\right) = \Delta \vec{p}$$

$$\vec{J}_{net} = \Delta \vec{p}$$

…which leads to a formula that equates net impulse with change in momentum.