Introduction to Physical Science

Momentum and Impulse

Presented by Robert Wagner

Linear Momentum

- Scientific definition of momentum
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- SI units power:
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Example

- Calculate the momentum of a 110 kg football player running at 8.00 m/s. Compare this to the momentum of a 0.410. kg football thrown at 25.0 m/s
  - Draw a sketch
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

$m_p = 110.\ kg\ ;\ v_p = 8.00\ m/s$

$m_b = 0.410\ kg\ ;\ v_b = 25.0\ m/s$

$p_p = m_p v_p = 110.\ kg \cdot 8.00\ m/s = 880.\ kg \cdot m/s$

$p_b = m_b v_b = (0.410\ kg)(25.0\ m/s) = 10.3\ kg \cdot m/s$

$$\frac{p_p}{p_b} = \frac{880.}{10.3} = 85.9$$

Momentum and Newton's Second Law

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  - Original formulation of Newton's Second Law
- If mass is constant, this becomes
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- First form can be used in situations where the mass is changing (rocket)

Example

- Tennis match serve reached a speed of 58 m/s. What is the force exerted on a 0.057 kg tennis ball by the racquet if the ball and racquet remain in contact for 5.0 ms?
  - Draw a sketch
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

$v_f = 58\ m/s\ ;\ m = 0.057\ kg\ ;\ \Delta t = 0.005\ s$

$$F_{net} = \frac{\Delta p}{\Delta t} = \frac{m\Delta v}{\Delta t}$$

$$F_{net} = \frac{(0.057\ kg)(58\ m/s)}{0.005\ s}$$

$$F_{net} = 660\ N$$

Impulse

- Impulse = change in momentum
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- Used in everyday life
  - If Δt is made larger, the force will be smaller because the momentum change is the same
- Examples: airbags, cars crumple in a collision, bending legs when landing from a jump

Example

- A car moving at 12 m/s crashes into a tree and stops in 0.28 s. Calculate the impulse and the force the seat belt exerts on a 78 kg passenger to bring them to a halt.
  - Draw a sketch
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

$v_i = 12\ m/s\ ;\ m = 78\ kg\ ;\ \Delta t = 0.28\ s$

$$\Delta p = m\Delta v = (78\ kg)(12\ m/s)$$

$$\Delta p = 940\ kg \cdot m/s$$

$$F_{net} = \frac{\Delta p}{\Delta t}$$

$$F_{net} = \frac{940\ kg \cdot m/s}{0.28\ s}$$

$$F_{net} = 3400\ N$$

Summary

- Linear momentum is defined to be the mass multiplied by the velocity
- The change in momentum was the original formulation of Newton's second law
- Impulse is defined as the change in momentum