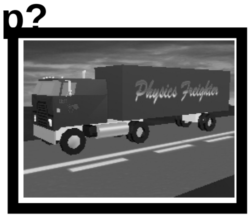
Momentum

and Impulse

Which would be harder to stop?



Why ? The truck has more mass.

Which would be harder to stop?

Velocity = 5 m/s

Velocity = 30 m/s

Why ? The red car is traveling faster.

Momentum depends on

- Mass (kg)
- Velocity (m/s)

Specifically

Momentum = mass x velocity

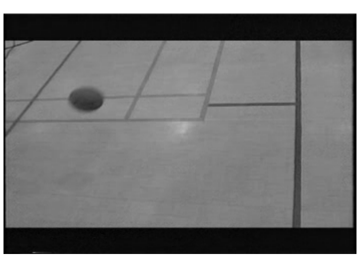
or

p = m x v

Momentum

- The strength of an object's motion
- A vector quantity
- Determined by both the object's mass and velocity
- Momentum (p) = mass (m) x velocity (v)

Momentum - Review



Newton's Second Law (revisited)

- Remember Newton's 2nd Law?
  - F=MA
- How does that compare to momentum?
  - P=MV
- Restating Newton's 2nd Law

$$F = ma = m\frac{\Delta v}{t} = \frac{\Delta p}{t}$$

Impulse

- Defined as the change in momentum
- Impulse – momentum theorem:
  - The impulse exerted on a body is equal to the change in the object's momentum

$F\Delta t = \Delta p$

$F\Delta t = mv_f - mv_i$

$\Delta p = mv_f - mv_i$

Changing an Object's Momentum

- How do we do it?
  - Apply a force
- What if we need to stop something quickly?
  - Apply more force
- What if there is a force limitation? (ie. Pain)
  - Increase amount of time

Airbags

- How does an air bag use this concept of impulse to decrease the amount of force on your body?

IT INCREASES THE AMOUNT OF TIME IT TAKES TO STOP

Stopping Distances

- The larger an object is, the harder it is to stop.
- If the same force is applied, a larger object will take more time to stop. This additional time means that it will travel a larger distance before stopping.

Momentum/Impulse Example

- A 2250 kg car traveling to the west is slowed uniformly from 20.0 m/s with a force of 8437.5 N for 4.00 s.
  - What is the change in the car's momentum?
  - What is the speed of the car after the brakes are applied?

Given: m = 2250 kg v_i = 20.0 m/s, West

F = 8437.5 N, East t = 4.00 s

Equations: $F\Delta t = \Delta p$

$F\Delta t = mv_f - mv_i$

$F\Delta t = mv_f - mv_i$

$(-8437.5\,N)(4.0\,s) = (2250\,kg)v_f - (2250\,kg)(20.0\,m/s)$

$-33750\,Ns = (2250\,kg)(v_f) - 45000\,kg\,m/s$

$11250\,kg \cdot m/s = (2250\,kg)(v_f)$

$v_f = 5\,m/s$

Application of Impulse

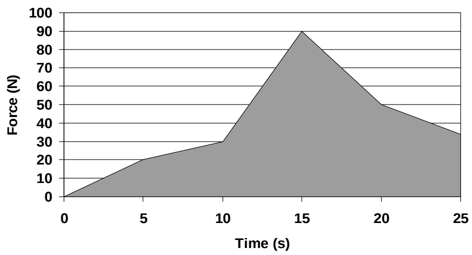
- Relating to sports…following through
  - Following through on a swing or a shot increases the contact time and therefore increases the change in the objects momentum. In other words, it goes farther.
  - Longer follow-throughs also improve directional control.

Momentum and Energy

- In some cases it might be necessary to relate these two quantities. With a little algebra, we get:

$$K = \frac{1}{2}mv^2 = \frac{(mv)^2}{2m} = \frac{p^2}{2m}$$

Interpreting Graphs



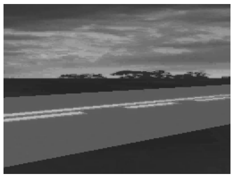
Use unit analysis to find the quantity that can be found using the area under the curve.

Interpreting Graphs

Law of Conservation of Momentum

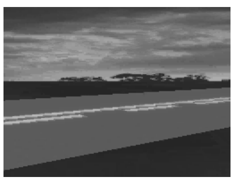
- The total momentum of the objects in a system does not change
- The momentum of any one object can change but the momentum lost by one object must be gained by the other objects
- Since momentum is a vector quantity, it may be necessary to find the components of a momentum vector to determine if it is conserved.
- Momentum is always conserved in an isolated system.

Types of collisions



An elastic collision is one in which both momentum and energy are conserved.

Types of collisions



An inelastic collision is one in which momentum is conserved but energy is not.

Law of Conservation of Momentum

- In both cases, momentum is conserved.
- So the following is true:
- total momentum = total momentum
  before collision after collision
- $p_{before} = p_{after}$
- $(p_{car} + p_{truck})_{before} = (p_{car} + p_{truck})_{after}$

Example

- A cue ball strikes a stationary eight ball. The cue ball had an initial velocity of 0.60 m/s. After the collision, the cue ball continues to move in the same direction with a speed of 0.25 m/s. What is the speed of the eight ball after the collision? (Assume both balls have a mass of 500g)
- Before :
  mass of cue = 0.5 kg   mass of 8 ball = 0.5 kg
  speed of cue = 0.60 m/s   speed of 8 ball = 0 m/s
- After :
  mass of cue = 0.5 kg   mass of 8 ball = 0.5 kg
  speed of clue = 0.25 m/s   speed of 8 ball = ?

Example (cont.)

Perfectly Inelastic Collisions

- When using the conservation of momentum with an perfectly inelastic collision, the two masses before the collision are combined after the collision and they both move together with the same velocity.
- $m_1v_1 + m_2v_2 = (m_1 + m_2)\ v_f$

Example 2

- A 30 g bullet is shot into a stationary 1kg wood block. The bullet embeds itself into the block and they both travel with a velocity of 8.0 m/s. What is the original velocity of the bullet?
- What type of collision?
  - Perfectly inelastic

Example 2 (cont.)

- $m_b v_b + m_w v_w = (m_b + m_w) v_f$
- (0.030 kg) v_b + (1 kg)(0 m/s)= (1 kg +0.030 kg)(8.0 m/s)
- then v_b = 275 m/s

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