Momentum

and Impulse

1

Which would be harder to stop?

Why ? The truck has more mass.

2

Which would be harder to stop?

Velocity = 5 m/s

Velocity = 30 m/s

Why ? The red car is traveling faster.

3

Momentum depends on

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

Specifically

Momentum = mass x velocity

or

p = m x v

4

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)

5

How do we change momentum?

- Change velocity..accelerate object.
  - How?
- Apply a force.
  -
- Restating Newton's 2nd Law

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

6

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

$$F\Delta t = \Delta p$$
$$F\Delta t = mv_f - mv_i$$
$$\Delta p = mv_f - mv_i$$

7

Changing an Object's Momentum

- What if we need to stop something quickly?
  - APPLY MORE FORCE
- What if there is a force limitation? (ie. Pain, egg toss)
  - INCREASE AMOUNT OF TIME

8

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

9

Stopping Distances

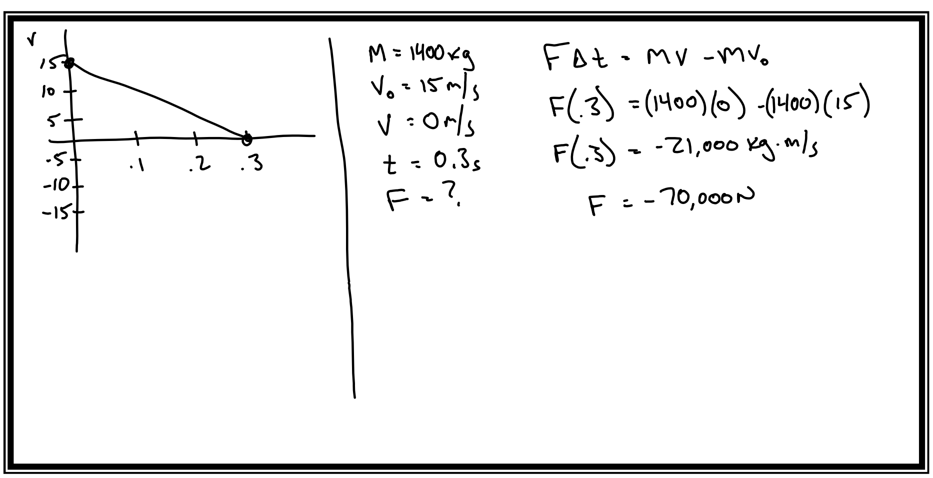
- The larger an object is, the harder it is to stop.
- If the same force is applied, a larger object will take more time to stop. This additional time means that it will travel a larger distance before stopping.

10

Momentum/Impulse Example

- A 1400 kg car moving east with a velocity of 15.0 m/s collides with a utility pole and is brought to rest in 0.30 seconds.
  - Draw a velocity - time graph for the car.
  - What is the force exerted on the car in the collision?

Momentum/Impulse Example

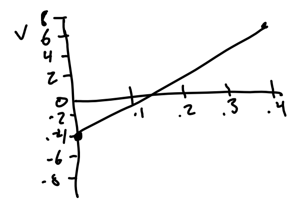


Impulse/Momentum Example 2

- A 0.45 kg volleyball travels west with a velocity of 4.0 m/s over the net. The ball is bounced back with a velocity of 7.0 m/s east. If the player applies a force of 13.0 N on the ball, how long was the player in contact with the ball?
- Draw a Velocity vs. Time graph for the volleyball

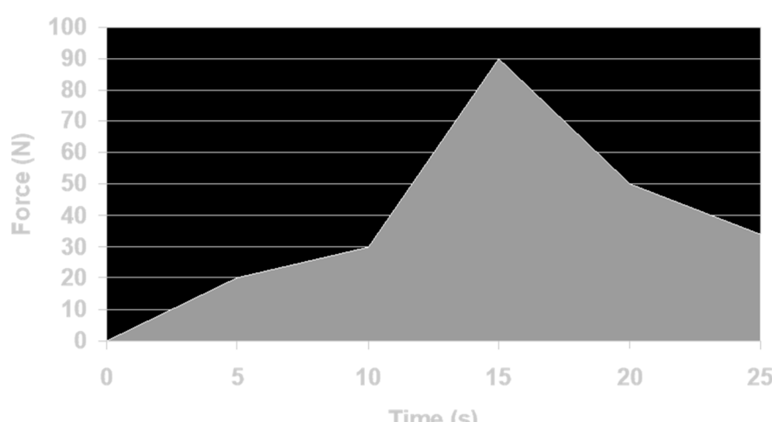
$m = .45 kg$
$v_0 = -4.0 m/s$
$v = 7.0 m/s$
$F = 13 N$
$t = ?$

$F\Delta t = mv - mv_0$
$13(t) = (.45)(7) - (.45)(-4)$
$13t = 4.95$
$t = .38 s$



13

Interpreting Graphs



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

14

Interpreting Graphs

$$Area = F \times t$$

$$Area = N \times s$$

$$Area = kg \cdot \frac{m}{s^2} \times s$$

$$Area = kg \cdot \frac{m}{s}$$

$$Area = mass \times velocity = momentum$$

15

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.

16

Law of Conservation of Momentum

When momentum is conserved, the following is true:

- total momentum of all objects before collision = total momentum of all objects after collision

- $(m_1v_1 + m_2v_2)_{before} = (m_1v_1 + m_2v_2)_{after}$

17

Example

- Two bumper cars are heading towards each other on a straight and level track. Car 1 has a mass of 1450 kg and is traveling at a velocity of 5.4 m/s. Car 2 has a mass of 1650 kg and is traveling at a velocity of 2.2 m/s. After the collision, Car 1 continues on its original path with a velocity of 1.3 m/s. What is the final velocity of car 2?

$(m_1v_1 + m_2v_2)_{BEFORE} = (m_1v_1 + m_2v_2)_{AFTER}$

$(1450)(5.4) + (1650)(-2.2) = (1450)(1.3) + (1650)(v_2)$

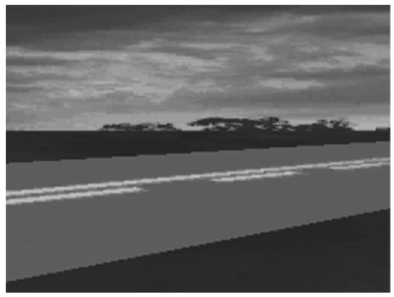
$7830 - 3630 = 1885 + 1650\,v_2$

$2315 = 1650\,v_2$

$1.4\ m/s = v_2$

18

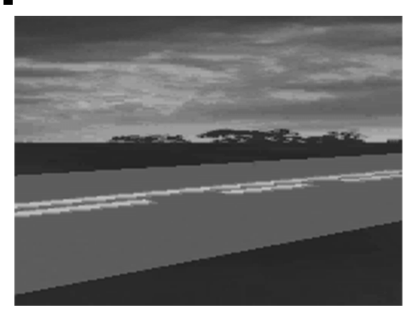
Types of collisions



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

19

Types of collisions



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

20

Perfectly Inelastic Collisions

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

21

Example 2

- A 30 g bullet is shot into a stationary 1 kg 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?

$(mv_{BULLET} + mv_{WOOD})_{BEFORE} = (mv_{BULLET} + mv_{WOOD})_{AFTER}$

$(.03)v_B + (1)(0) = (.03 + 1.0)(8\ m/s)$

$.03v_B = 8.24$

$v_B = 275\ m/s$

22