Momentum & Impulse

Outcome:

S2-3-08 Define momentum and impulse, and qualitatively relate impulse to a change in momentum for everyday situations. *Include: Car collisions, bumpers, seat belts, air bags, etc.*

Momentum…

Would you rather collide with a train moving at 2 m/s or a mosquito moving at the same speed?

What makes an object difficult to **BRING TO REST**?

MOMENTUM (p) is a term we use in physics to describe a **QUANTITY OF MOTION**.

→If an **OBJECT IS IN MOTION** then it has **MOMENTUM**.

Science Of NFL Football: Newton's Third Law Of Motion - Science360 - Video Library

Momentum…

What are the characteristics of momentum?

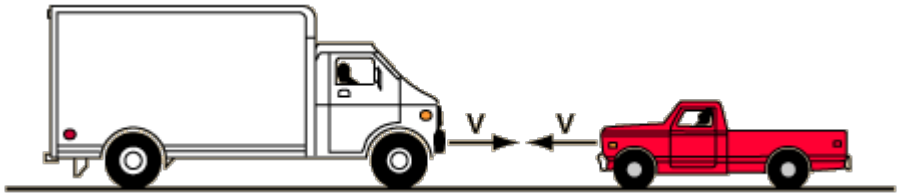
1. **MASS**
   - **MORE MASS** means more resistance to **ACCELERATION**, and the more difficult it is to bring the object to rest.

     → ***Stopping a train vs. a mosquito.***

2. **VELOCITY**
   - Objects that are moving **FAST** are also **HARD TO STOP**.

     → ***Bullets have small mass but are hard to stop***

If we wish to bring an object in motion to rest, we must take into account its **VELOCITY** as well as its **MASS**. Newton called this the principle of **MOMENTUM**.



Momentum…

Simply stated, if a moving object has **MORE MASS**, it has **MORE MOMENTUM**, and if an object has **MORE VELOCITY**, it has **MORE MOMENTUM**.

→ ***Harder to bring to rest!***

How much momentum does a boulder resting on the side of the road have?

Momentum…

The Equation for Momentum (p)

The mathematical relationship for momentum (p) is:

$$p = mv$$

Where:

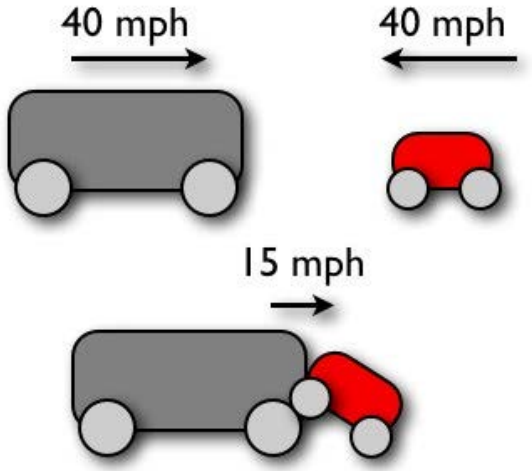
p = **MOMENTUM in kg·m/s or kg·km/h**

m = **MASS in kg**

v = **VELOCITY in m/s or km/h**

Momentum is a **VECTOR**.

→ Direction of velocity = direction of momentum.



Momentum…

Example:

A car travelling at 45.0 km/h [East] has a mass of 1250 kilograms. What is the momentum of the car?

$V = 45\ km/h \div 3.6 = 12.5\ \frac{m}{s}$

$m = 1250\ kg$

$p = m \cdot v$

$p = (1250\ kg)(12.5\ \frac{m}{s})$

$P = 15625\ kg\,m/s \quad [E]$

Momentum…

Try this one…

A snowmobile is travelling north at 120km/h. It has a mass of 250kg. Find its momentum in kg·m/s.

$m = 250\,kg$

$V = 120\,km/hr \div 3.6 = 33.3\,m/s$

$p = m \cdot v$

$= (250\,kg)(33.3\,m/s)$

$= 8332.5\,kg \cdot m/s\ [N]$

Impulse…

Recall:

- In order to **CHANGE MOTION** we need to apply an **UNBALANCED FORCE**.

If we continue to apply a force for a long period of time, the object will continue to **ACCELERATE**, either **INCREASING** or **DECREASING** its **VELOCITY**.

→ As the **VELOCITY** of the object changes, so does its **MOMENTUM**.

We call the amount of **FORCE** and the **TIME** during which the force is applied the **IMPULSE**.

- If we have **MORE FORCE**, we have **MORE IMPULSE**.
- Additionally, if we apply the force for **A LONGER PERIOD OF TIME**, we also have **MORE IMPULSE (I)**.

I

Force, Impulse & Collisions - Science360 - Video Library

Impulse…

Example:
When Stopping a car going 60km/hr, you could:

1. ***Slam on the breaks and stop quickly***
   → big force, short time

2. ***Gently break and stop slowly***
   → small force, long time

***Both have the same **IMPULSE**, since they are changing the same amount of momentum.

Impulse…

The mathematical relationship for impulse is:

$$I = Ft$$

Where:

I = **IMPULSE in N·s (Newton seconds)**

F = **FORCE in N**

t = **TIME in s**

Impulse is also a **VECTOR** quantity.

→ ***The direction of force = the direction of Impulse***

Remember that any **UNBALANCED** force will cause an object to **ACCELERATE** (either **SPEED UP** or **SLOW DOWN**).

- If the force acts **OPPOSITE** to the object's motion
  → The object **SLOWS DOWN**.

- If a force acts in the **SAME DIRECTION** as the object's motion,
  →The object **SPEEDS UP**.

Impulse…

Example:

Find the impulse if 150N of force are applied for 20s.

$F = 150\,N$

$t = 20\,s$

$I = F \cdot t$

$I = (150\,N)(20\,s)$

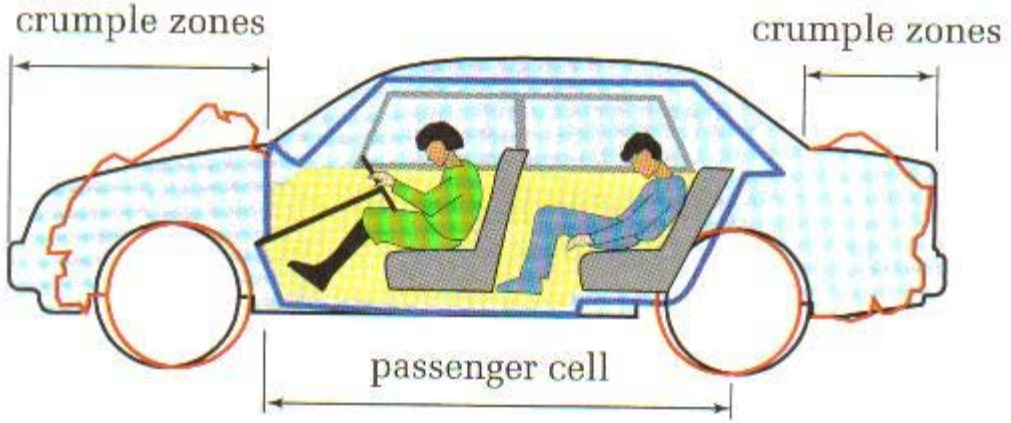
$I = 3000\,N \cdot s$

Impulse…

The change in **MOMENTUM** will **ALWAYS EQUAL** the **IMPULSE**.

$$F\Delta t = m\Delta v$$

The Impulse — The Change in Momentum



Impulse…

If you play sports, your coaches have been teaching you about impulse and momentum for many years.

Example: Hitting a ball (golf, baseball, volleyball, etc)
To improve your performance, your coach may suggest:

1. **Build Strength**
   - Building strength allows you to hit the ball with more **FORCE**.
   - A **LARGER FORCE** acting over the **SAME TIME** gives a larger **IMPULSE**

(FORCE) *(time)* ***= IMPULSE***

Impulse…

2. **Follow Through**
   - When you follow through, you increase the amount of **TIME** the force is **APPLIED**.
   - The **SAME FORCE** applied over a **LONGER** time gives more **IMPULSE**.

(force) ***(TIME) = IMPULSE***

Reducing the force during an impulse…

A 2 000-kg car moving at 50 km/h has a tremendous amount of momentum. In order to stop the car, the car's momentum must be reduced to zero. The only way to do this is to apply an impulse opposite to the car's motion.

This car can only be stopped one of 2 ways:

1. Safely using the **BREAKS**
   → ***Small force over long period of time***

2. **COLLISION** with another object
   → ***Large force over a short time***

Either way, the impulse would be the same, but the larger force is much more destructive to the car and passengers.

Reducing Force during an Impulse…

To reduce injuries during a collision, we need to reduce the **FORCE** of the impulse. Ways to do this would be to:

- **LENGTHEN THE TIME** during which the force is applied.
- Prevent/minimize the **VIOLENT SECOND COLLISIONS**

There are many **DEVICES** that are now used to help lessen the damage caused by second collisions, such as air bags and seat belts.

'59 BEL AIR VS '09 MALIBU

Cushioning Devices…

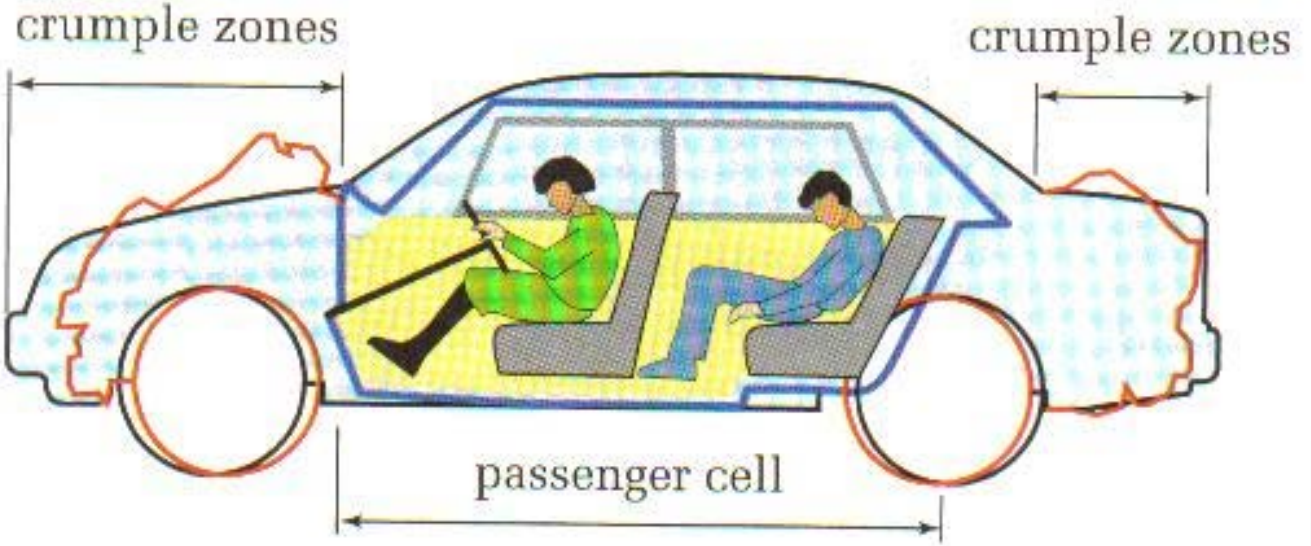
1. **BUMPERS**

Bumpers are designed to minimize the damage to a vehicle in a collision by **ABSORBING** some of the **IMPULSE**. Today, cars use bumpers that have the ability to **COMPRESS** because of their material and/or through the use of a special kind of bumper mechanism.

Cushioning Devices…

2. **CRUMPLE ZONES**

A crumple zone is a part of a car that is designed to compress during an accident to absorb the impulse from an impact. A crumple zone **INCREASES** the amount of **TIME** it takes the **CAR TO STOP**, and therefore **DECREASES** the amount of **FORCE** in the impulse. Crumple zones mean that the impulse is reduced before it is passed on to the occupant compartment.



Cushioning Devices…

3. **PADDED DASHBOARDS**

If a driver or occupant hits the dashboard in a collision, then the force and time required to stop their momentum is exerted by the dashboard. Padded dashboards **INCREASE** the **DURATION** of the impact, minimizing the amount of the force of the impulse.

4. **SEAT BELTS**

In a vehicle collision, the seat belt restrains the occupant and **PREVENTS** him or her from impacting the steering wheel, dashboard or windshield, and **HELPS ABSORB** the occupant's forward **MOMENTUM**.

INJURIES are **REDUCED** as the impact force is distributed to the **STRONGEST PARTS** of the body.

Spreading the force over a larger area, the area of the belts, also reduces the force acting on a specific area.

An unrestrained occupant who is thrown from a vehicle is likely to be severely injured.

Cushioning Devices…

4. **AIR BAGS**

Air bags can be used to minimize the force on a person involved in a collision. Air bags **CUSHION THE BLOW** by **INCREASING** the amount of **TIME** during which the force is applied. Since the time of impact increases, the amount of force of the impulse decreases.

Understanding Car Crashes: It's Basic Physics - YouTube