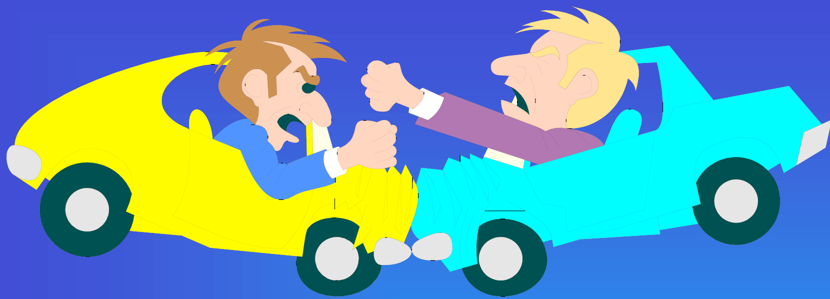
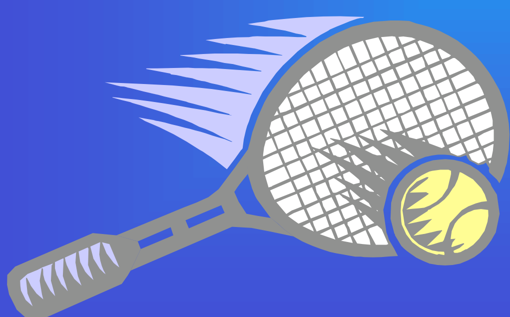


Momentum and Impulse



More force is needed to quickly stop a baseball thrown at 95 mph than to quickly stop a baseball thrown at 45 mph, even though they both have the **same mass**.

More force is needed to quickly stop a **train** moving at 45 mph than to quickly stop A **car** moving at 45 mph, even though they both have the **same speed**.

Both mass and **velocity** are important factors when considering the force needed to change the motion of an object.

MOMENTUM

the product of mass and velocity of an object

momemtum = mass x velocity

$$p = mv$$

p = momentum; has units of mass x velocity
m = mass; usually measured in kg
v = velocity; usually measured in m/s or km/hr

Momentum is a vector,
so direction is important.

An object's momentum will change if its **mass** and/or **velocity** (speed and direction) changes.

According to Newton's laws,
a net force causes an object to accelerate,
or change its velocity.

A net force, therefore, causes a change in an object's momentum.

$F = ma$ (Newton's Second Law)

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

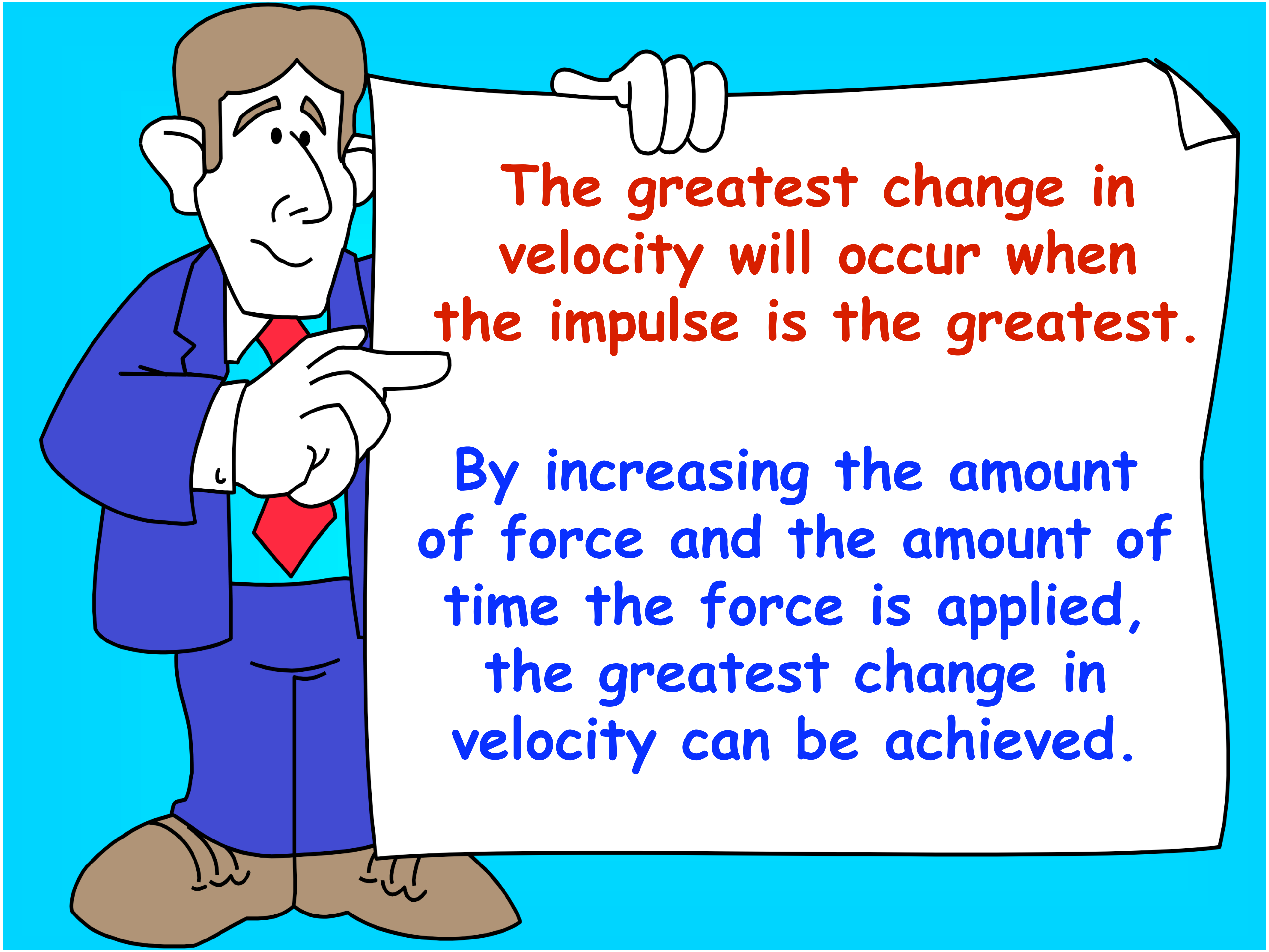
$$F\Delta t = m\Delta v = \Delta p$$

Impulse = change in momentum

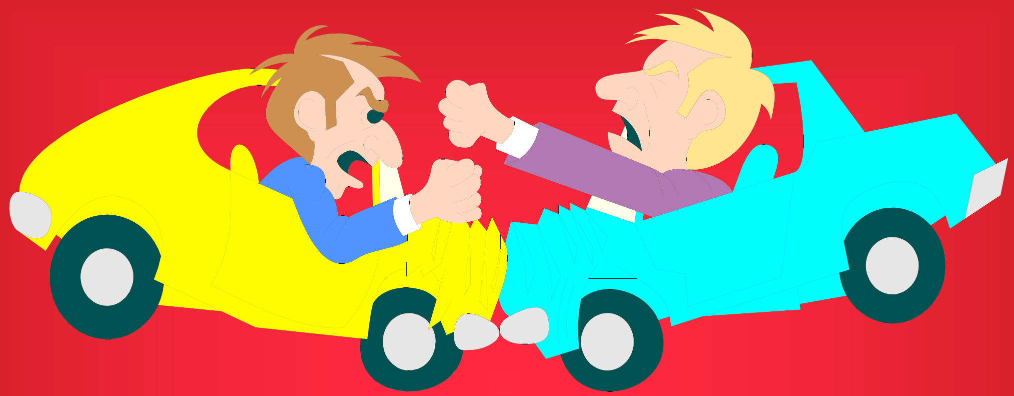
Impulse

the product of the average force and the time interval during which the force is exerted

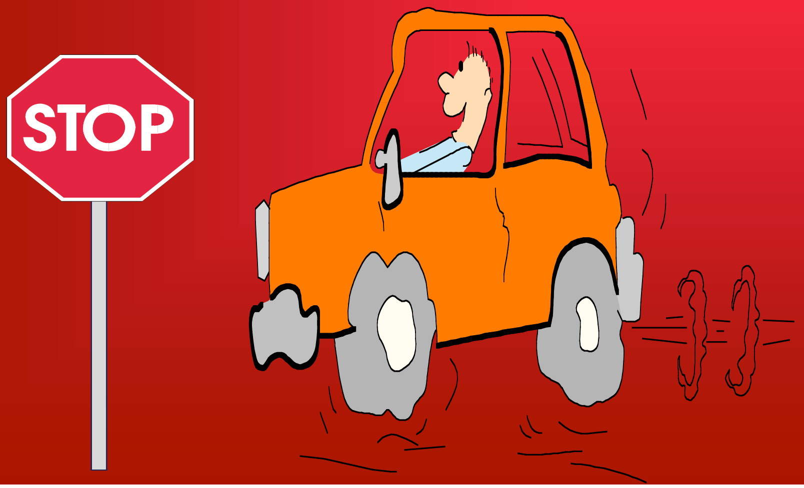
An impulse, imparted to an object, causes it to change its momentum. This usually means a change in velocity.


The greatest change in velocity will occur when the impulse is the greatest.
By increasing the amount of force and the amount of time the force is applied, the greatest change in velocity can be achieved.

A 1000 kg car moving at 30 m/s (p = 30,000 kg m/s) can be stopped by 30,000 N of force acting for 1.0 s (a crash!)



or by 3000 N of force acting for 10.0 s (normal stop)



The Law of Conservation of Momentum

The momentum of any closed, isolated system does not change.

The momentum before an event, p_1, is equal to the momentum after the event, p_2.

$$p_1 = p_2$$

$$m_1v_1 + m_2v_2 + m_3v_3 + \ldots = m_1V_1 + m_2V_2 + m_3V_3 + \ldots$$

where v is the velocity before the event and V is the velocity after

Law of Conservation of Energy

"Energy can be neither created nor destroyed. It may only change forms."

Σ all types of energy before the event

= Σ all types of energy after the event

Examples:

- A dropped object loses gravitational PE as it gains KE.
- A block slides across the floor and comes to a stop.
- A compressed spring shoots a ball into the air.

Collisions

Elastic

Momentum is conserved.

Σ p before collision = Σ p after collision

Bouncy collisions: Momentum is transferred.

Inelastic

Momentum is conserved.

Σ p before collision = Σ p after collision

Sticky collisions: Momentum is shared.

Examine elastic and inelastic collisions in one and two dimensions at these simulation sites: link1, link2, link3, link4, link5

Examine the conservation of energy at these simulation sites: link1, link2, link3, link4