Impulse and Momentum

AP Physics C

Impulse = Momentum

Consider Newton's 2nd Law and the definition of acceleration

Impulse-Momentum Theorem

$J = \Delta p$

$Ft = \Delta mv$

$$\frac{F_{Net}}{m} = a, \quad a = \frac{\Delta v}{t}$$

$$\frac{F_{Net}}{m} = \frac{\Delta v}{t} \rightarrow Ft = \Delta mv$$

$$Ft = \text{Impulse(J)}$$

$$\Delta mv = \text{Momentum(p)}$$

Units of Impulse: **Ns**

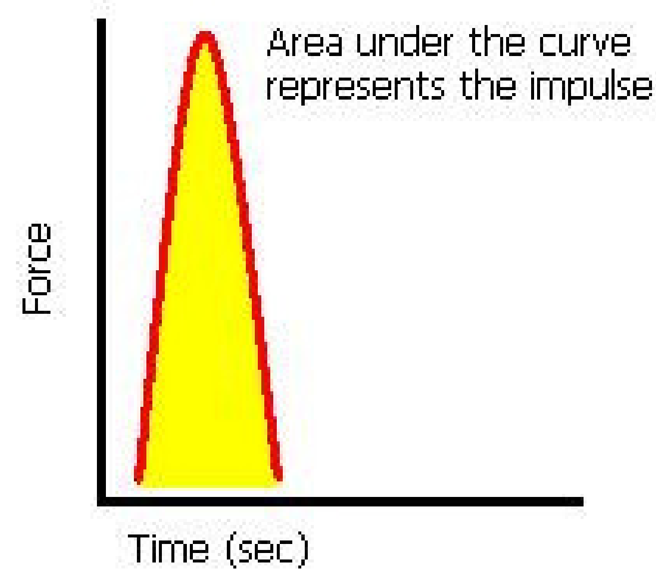
Units of Momentum: **Kg x m/s**

Momentum is defined as *"Inertia in Motion"*

Calculus Variations

$$F_{net} = \frac{dp}{dt}$$

$$J = \int F_{net}\,dt = \Delta p$$

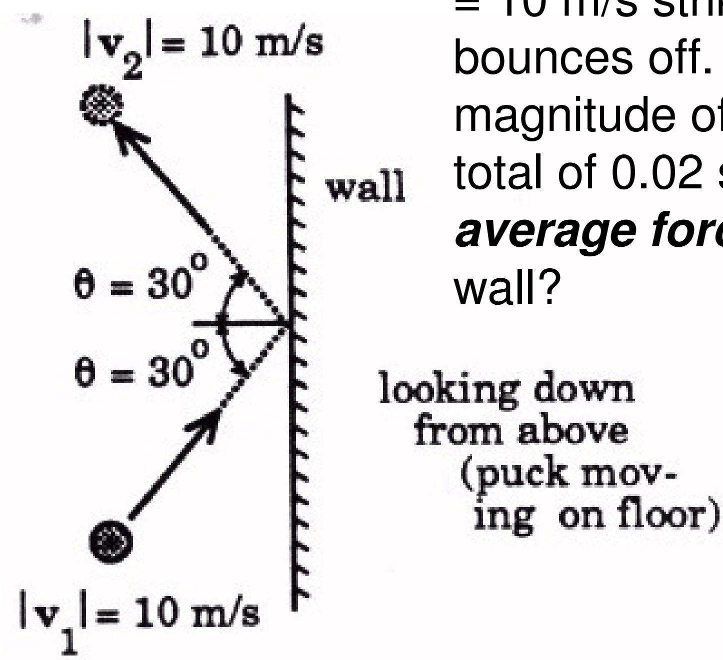


The force is the time derivative of momentum.

The impulse can be found by integrating under the curve of a Force vs. Time graph

Example

A 2-kg sliding puck whose initial velocity magnitude is v_1 = 10 m/s strikes a wall at a 30 degree angle and bounces off. If it leaves the wall with a velocity magnitude of v_2 = 10 m/s, and if the collision takes a total of 0.02 seconds to complete, what was the ***average force*** applied to the puck by the wall?

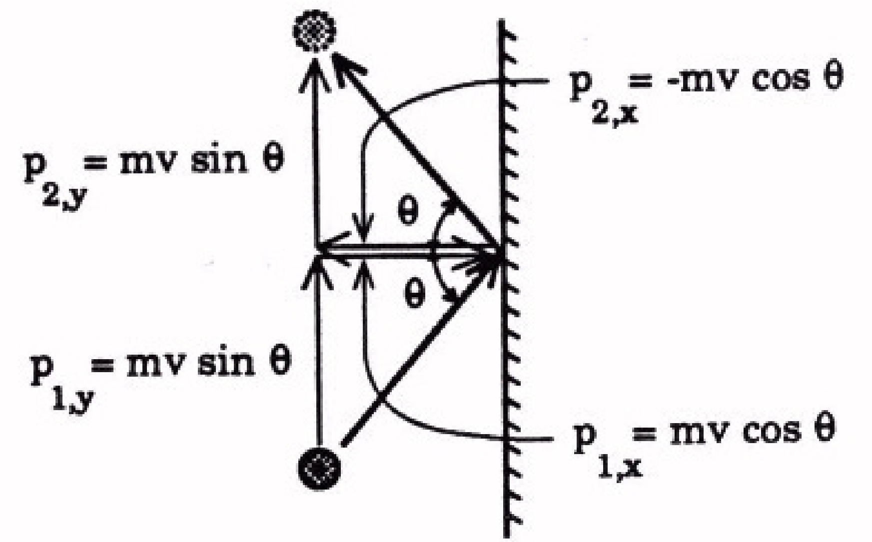


There is something you need to consider:

Momentum is a VECTOR!!!

Let's look at this problem using a X-Y axis for reference

Example cont'

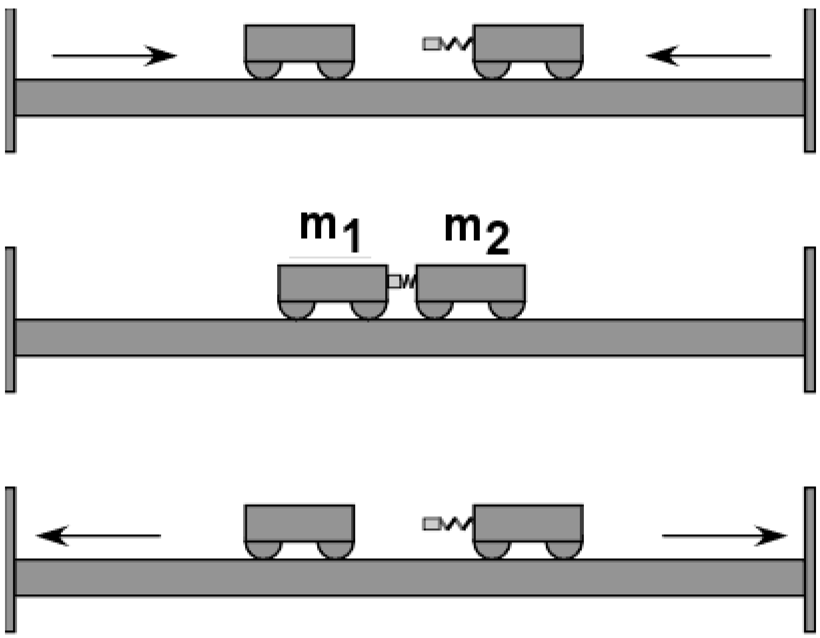


$$\Delta p_x = p_x - p_{0x}$$
$$\Delta p_x = (-mv\cos\theta) - (mv\cos\theta)$$
$$\Delta p_x = -2mv\cos\theta$$
$$\Delta p_x = -2(2)(10)(\cos 30)$$
$$\Delta p_x = -34.6 kg - m/s$$
$$F_{net(x)} = \frac{\Delta p_x}{\Delta t} = \frac{-34.6}{0.02} = -1730N$$

If we did the same thing for the Y direction we would discover that the Force Net is equal to ZERO!

The temptation is to treat momentum as a SCALAR...DO NOT DO THIS! SIGNS COUNT!

How about a collision?



$$F_1 = -F_2 \quad t_1 = t_2$$

$$(Ft)_1 = -(Ft)_2$$

$$J_1 = -J_2$$

Consider 2 objects speeding toward each other. When they collide......

Due to Newton's 3rd Law the FORCE they exert on each other are EQUAL and OPPOSITE.

The TIMES of impact are also equal.

Therefore, the IMPULSES of the 2 objects colliding are also EQUAL

How about a collision?

If the Impulses are equal then the MOMENTUMS are also equal!

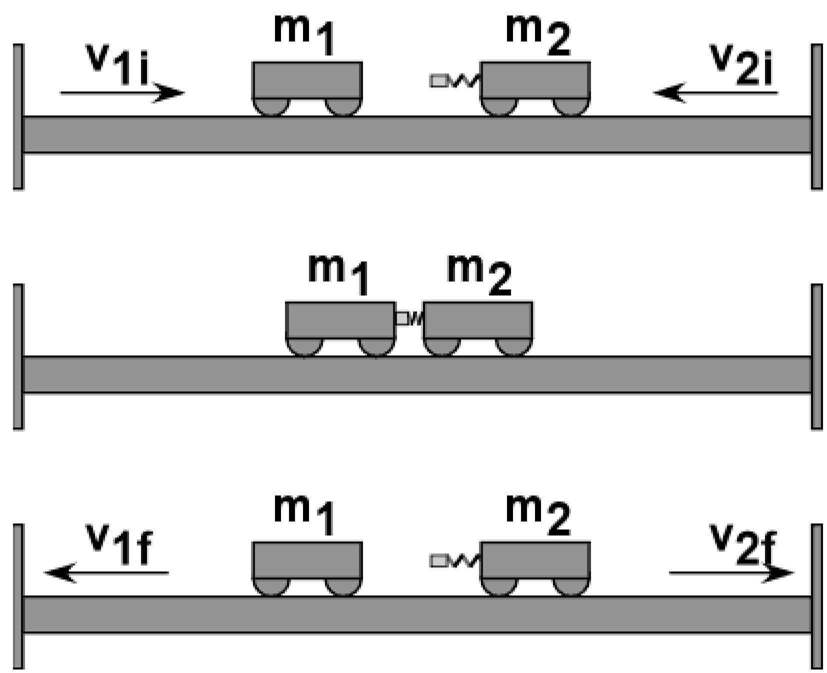
$$J_1 = -J_2$$

$$p_1 = -p_2$$

$$m_1 \Delta v_1 = -m_2 \Delta v_2$$

$$m_1 (v_1 - v_{o1}) = -m_2 (v_2 - v_{o2})$$

$$m_1 v_1 - m_1 v_{o1} = -m_2 v_2 + m_2 v_{o2}$$

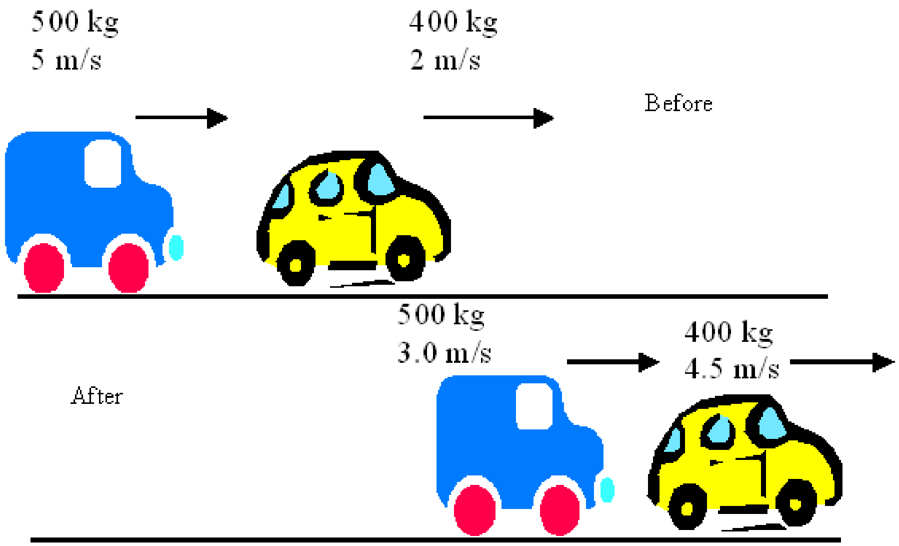


$$\sum p_{before} = \sum p_{after}$$

$$m_1 v_{o1} + m_2 v_{o2} = m_1 v_1 + m_2 v_2$$

Momentum is conserved!

The Law of Conservation of Momentum: ***"In the absence of an external force (gravity, friction), the total momentum before the collision is equal to the total momentum after the collision."***



$$p_{o(truck)} = mv_o = (500)(5) = 2500 kg*m/s$$

$$p_{o(car)} = (400)(2) = 800 kg*m/s$$

$$p_{o(total)} = 3300 kg*m/s$$

$$p_{truck} = 500*3 = 1500 kg*m/s$$

$$p_{car} = 400*4.5 = 1800 kg*m/s$$

$$p_{total} = 3300 kg*m/s$$

Several Types of collisions

Sometimes objects stick together or blow apart. In this case, momentum is ALWAYS conserved.

$$\sum p_{before} = \sum p_{after}$$

$$m_1 v_{01} + m_2 v_{02} = m_1 v_1 + m_2 v_2 \longrightarrow$$ When 2 objects collide and DON'T stick

$$m_1 v_{01} + m_2 v_{02} = m_{total} v_{total} \longrightarrow$$ When 2 objects collide and stick together

$$m_{total} v_{o(total)} = m_1 v_1 + m_2 v_2 \longrightarrow$$ When 1 object breaks into 2 objects

Elastic Collision = Kinetic Energy is Conserved

Inelastic Collision = Kinetic Energy is NOT Conserved

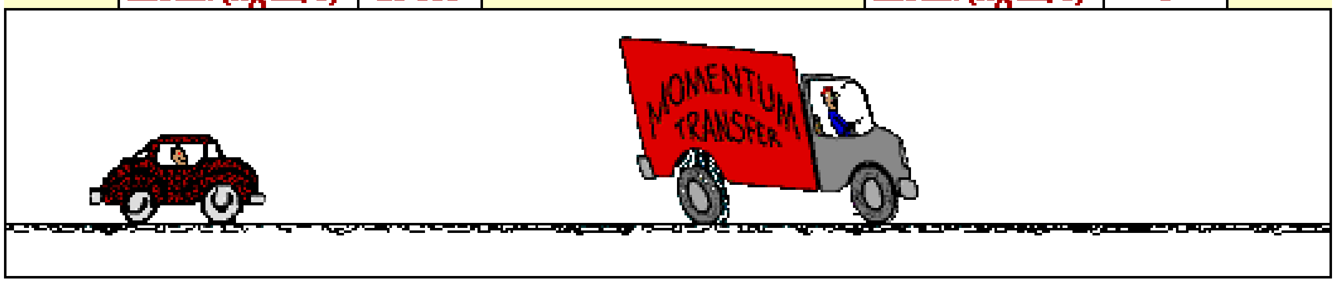
Elastic Collision

Car

mass (kg)	1000
vel. (m/s)	20.0
mom. (kg m/s)	20 000

Truck

mass (kg)	3000
vel. (m/s)	0.0
mom. (kg m/s)	0



$$KE_{car}(Before) = \frac{1}{2}mv^2 = 0.5(1000)(20)^2 = 200{,}000\,J$$

$$KE_{truck}(After) = 0.5(3000)(10)^2 = 150{,}000\,J$$

$$KE_{car}(After) = 0.5(1000)(-10)^2 = 50{,}000\,J$$

Since KINETIC ENERGY is conserved during the collision we call this an **ELASTIC COLLISION**.

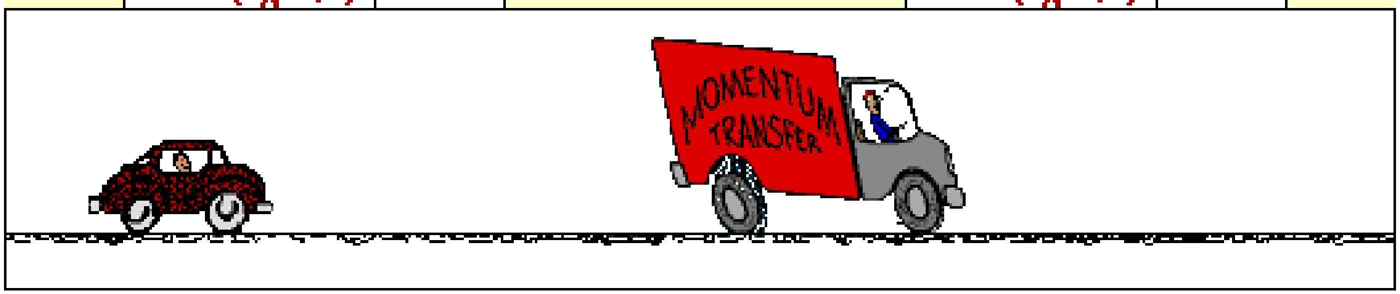
Inelastic Collision

Car

mass (kg)	1000
vel. (m/s)	20.0
mom. (kg m/s)	20 000

Truck

mass (kg)	3000
vel. (m/s)	0.0
mom. (kg m/s)	0



$$KE_{car}(Before) = \frac{1}{2}mv^2 = 0.5(1000)(20)^2 = 200{,}000\,J$$

$$KE_{truck/car}(After) = 0.5(4000)(5)^2 = 50{,}000\,J$$

Since KINETIC ENERGY was NOT conserved during the collision we call this an **INELASTIC COLLISION**.