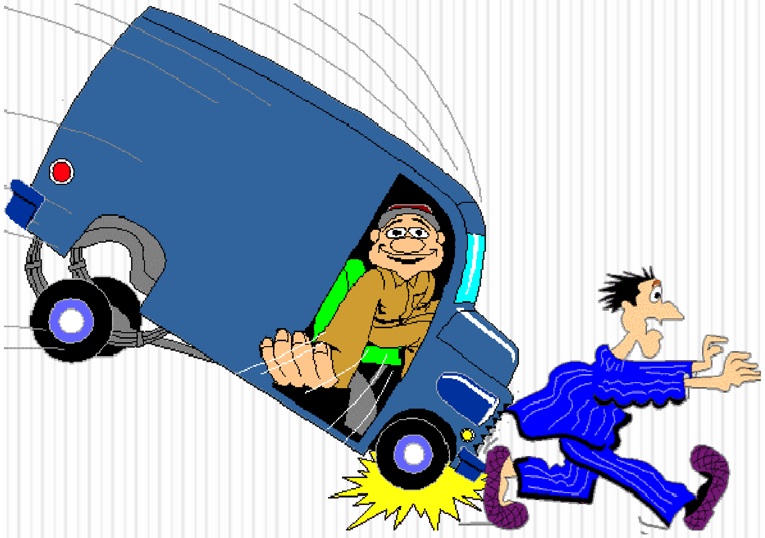
Impulse and Momentum

AP Physics B



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"*

Example

A 100 g ball is dropped from a height of h = 2.00 m above the floor. It rebounds vertically to a height of h'= 1.50 m after colliding with the floor. (a) Find the momentum of the ball immediately before it collides with the floor and immediately after it rebounds, (b) Determine the average force exerted by the floor on the ball. Assume that the time interval of the collision is 0.01 seconds.

$$E_B = E_A$$
$$U_o = K$$
$$mgh_o = \tfrac{1}{2} mv^2$$
$$v = \sqrt{2gh_o} = \sqrt{2*9.8*2} = 6.26\ m/s$$

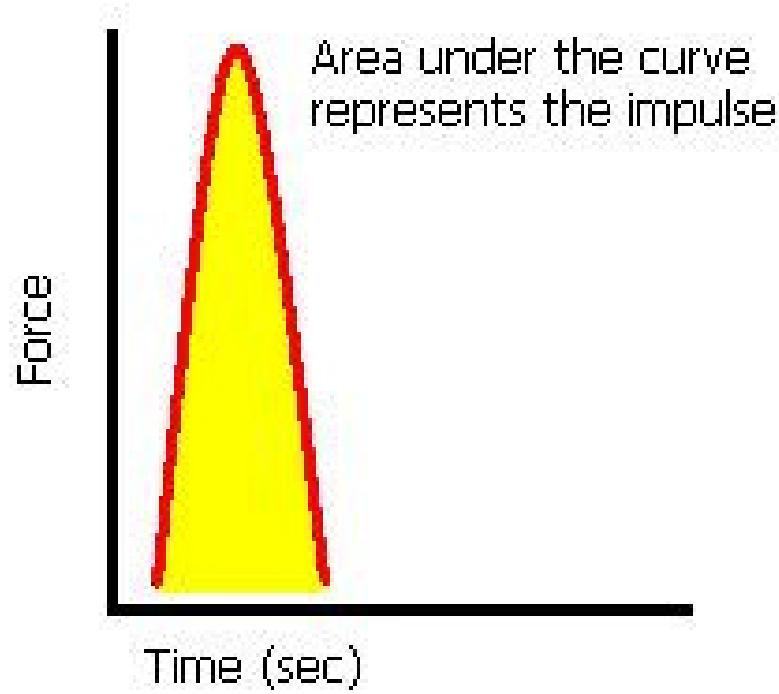
$$E_B = E_A$$
$$K_o = U$$
$$v = \sqrt{2gh} = \sqrt{2*9.8*1.5} = 5.4\ m/s$$

$$\vec{p} = m\Delta\vec{v}$$
$$p_{before} = 0.100(-6.26) = -0.626\ kg*m/s$$
$$p_{after} = 0.100(5.4) = 0.54\ kg*m/s$$

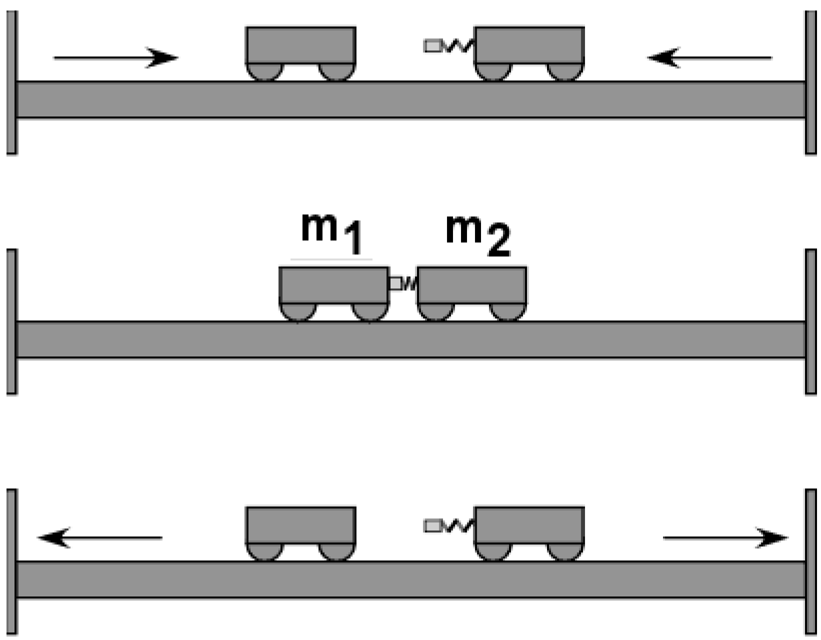
$$Ft = m\Delta v = m(v - v_o)$$
$$F(0.01) = 0.100(5.4 - (-6.26))$$
$$F = 116.6N$$

Impulse is the Area

Since J=Ft, Impulse is the AREA of a Force vs. Time graph.



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……

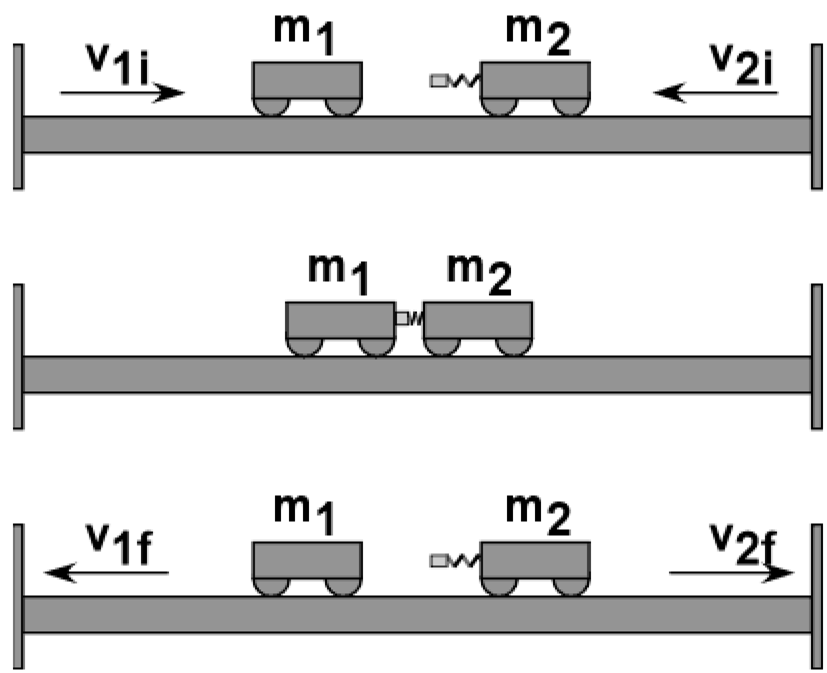
Due to Newton's 3rd Law the FORCE they exert on each other are EQUAL and OPPOSITE.

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!



$$J_1 = -J_2$$

$$p_1 = -p_2$$

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

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

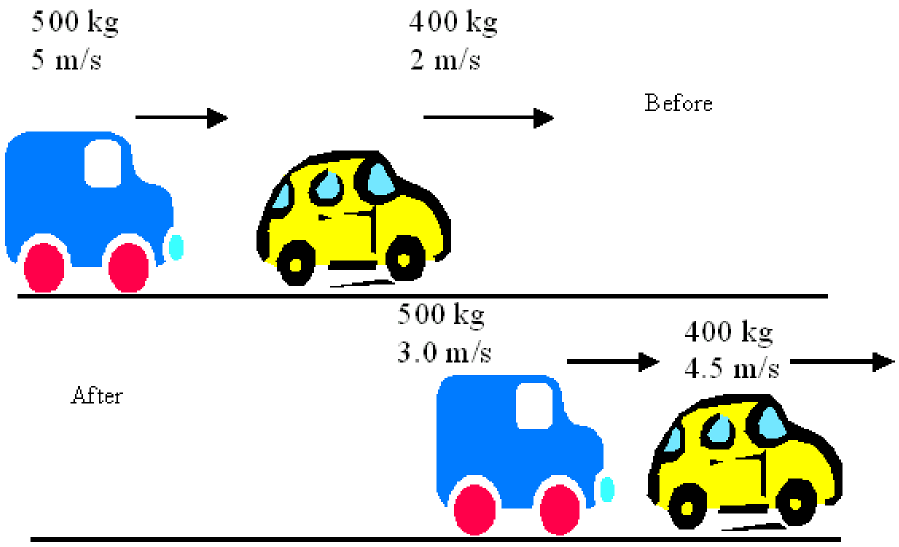
$$m_1 v_1 - m_1 v_{o1} = -m_2 v_2 + m_2 v_{o2}$$

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

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

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.

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

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

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

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

Elastic Collision = Kinetic Energy is Conserved

Inelastic Collision = Kinetic Energy is NOT Conserved

Example

A bird perched on an 8.00 cm tall swing has a mass of 52.0 g, and the base of the swing has a mass of 153 g. Assume that the swing and bird are originally at rest and that the bird takes off horizontally at 2.00 m/s. If the base can swing freely (without friction) around the pivot, how high will the base of the swing rise above its original level?

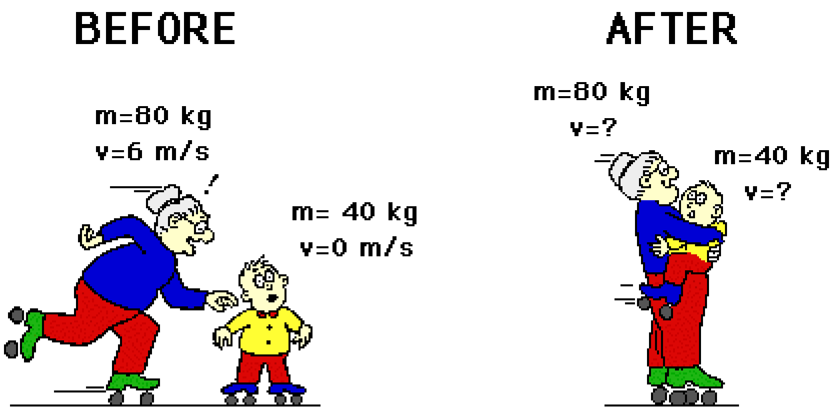
How many objects due to have BEFORE the action? 1

How many objects do you have AFTER the action? 2

$$p_B = p_A$$
$$m_T v_{oT} = m_1 v_1 + m_2 v_2$$
$$(0.205)(0) = (0.153) v_{1(swing)} + (0.052)(2)$$
$$v_{swing} = \mathbf{-0.680\ m/s}$$

$$E_B = E_A$$
$$K_{o(swing)} = U_{swing}$$
$$\tfrac{1}{2} m v_o^2 = mgh$$
$$\frac{v_o^2}{2g} = h = \frac{(0.68)^2}{19.6} = \mathbf{0.024\ m}$$

Example



Granny (m=80 kg) whizzes around the rink with a velocity of 6 m/s. She suddenly collides with Ambrose (m=40 kg) who is at rest directly in her path. Rather than knock him over, she picks him up and continues in motion without "braking." Determine the velocity of Granny and Ambrose.

How many objects do I have before the collision?

2

How many objects do I have after the collision?

1

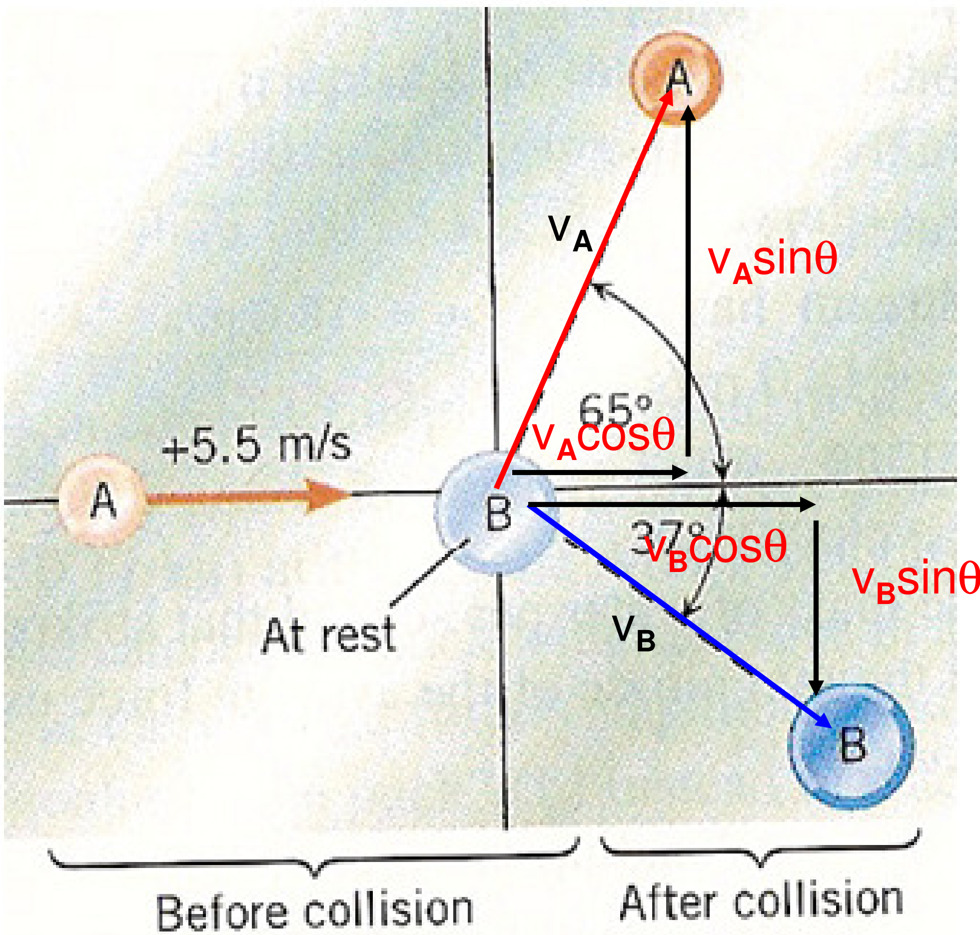
$$p_b = p_a$$

$$m_1 v_{o1} + m_2 v_{o2} = m_T v_T$$

$$(80)(6) + (40)(0) = 120 v_T$$

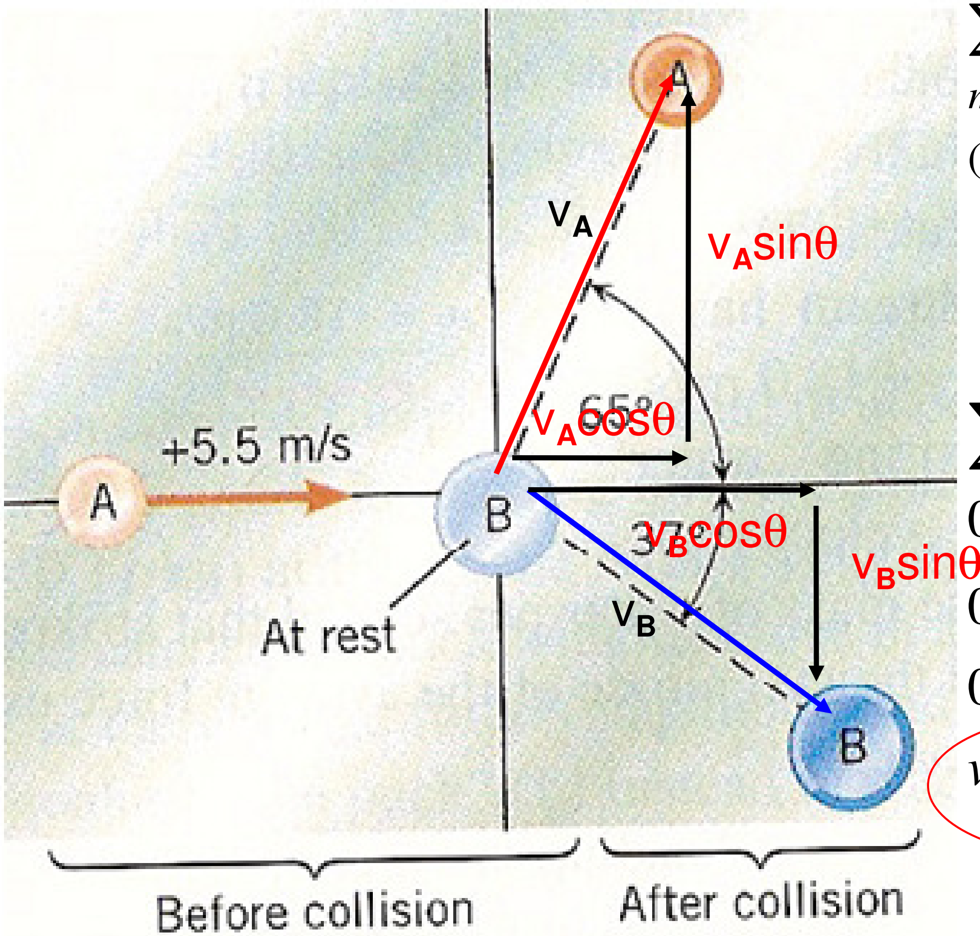
$$v_T = \text{4 m/s}$$

Collisions in 2 Dimensions



The figure to the left shows a collision between two pucks on an air hockey table. Puck A has a mass of 0.025-kg and is moving along the x-axis with a velocity of +5.5 m/s. It makes a collision with puck B, which has a mass of 0.050-kg and is initially at rest. The collision is NOT head on. After the collision, the two pucks fly apart with angles shown in the drawing. Calculate the speeds of the pucks after the collision.

Collisions in 2 dimensions



$$\sum p_{ox} = \sum p_x$$

$$m_A v_{oxA} + m_B v_{oxB} = m_A v_{xA} + m_B v_{xB}$$

$$(0.025)(5.5) + 0 = (.025)(v_A \cos 65) + (.050)(v_B \cos 37)$$

$$0.1375 = 0.0106 v_A + 0.040 v_B$$

$$\sum p_{oy} = \sum p_y$$

$$0 = m_A v_{yA} + m_B v_{yB}$$

$$0 = (0.025)(v_A \sin 65) + (0.050)(-v_B \sin 37)$$

$$0.0300 v_B = 0.0227 v_A$$

$$v_B = 0.757 v_A$$

Collisions in 2 dimensions

$$0.1375 = 0.0106v_A + 0.040v_B$$

$$v_B = 0.757v_A$$

$$0.1375 = 0.0106v_A + (0.050)(0.757v_A)$$

$$0.1375 = 0.0106v_A + 0.03785v_A$$

$$0.1375 = 0.04845v_A$$

$$v_A = 2.84m/s$$

$$v_B = 0.757(2.84) = 2.15m/s$$