Lesson 4 Conservation of Momentum

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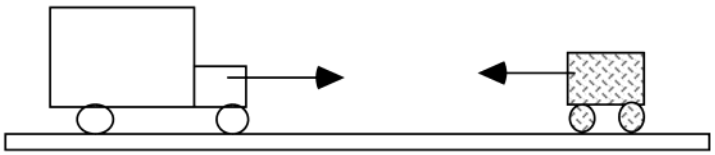
Physics 11 Unit 6 Lesson 4 Name:

Lesson 4 Conservation of Momentum

•example 1: In the collision seen below, which vehicle experiences the larger force?

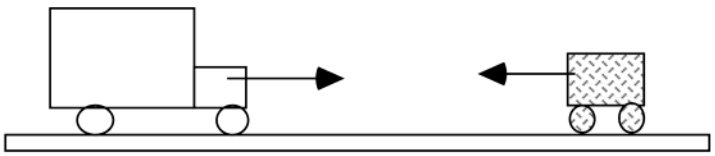
a) truck b) car c) both the same



Using principles of physics, explain your answer

Newton's 3rd (forces come in pairs)

•example 2: Why is it that the car and car driver are almost always worse off as a result of this collision?



$F = ma$

Explain your answer

$Ma = m$ larger accel.

•Note: a closed system is one that is cut-off from the outside world. This means that there are no net external forces. Examples of such a system would include:

frictionless surfaces systems in deep intergalactic space

systems floating on the water rolling objects

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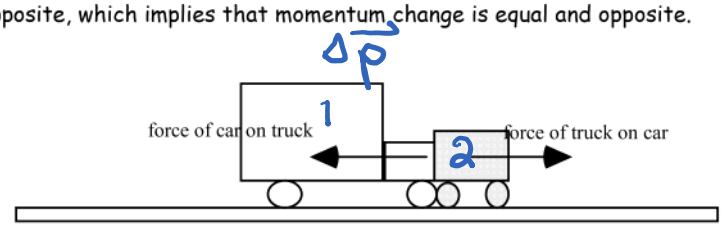
•for collisions in a closed system the contact forces are governed by Newton's Third Law. So forces are equal and opposite, which implies that momentum change is equal and opposite.



$F_1 = -F_2$ Newton's 3rd Law

$F_1 \Delta t = -F_2 \Delta t$ multiply by time

$\Delta p_1 = -\Delta p_2$ def'n of impulse

•example 3: what does it mean to say that momentum change is equal and opposite? For instance if the car above loses 20 units of momentum, what happens to the truck?

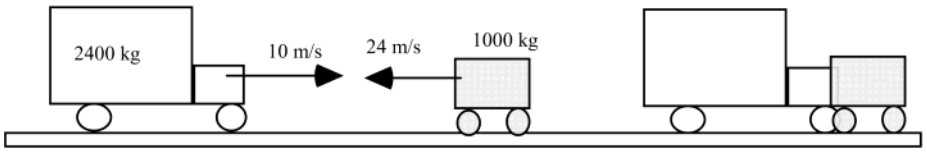
~~Gains 20 units of momentum~~

•since momentum change is equal and opposite, the momentum for the system is not gained or lost, it is simply transferred from one object to another.

We say that momentum is "conserved".

•example 4: if conditions are such that the car and truck end up at rest after the collision, how can we say that the momentum has not been lost for the system?

$\vec{p} = m\vec{v}$



$\vec{p}_{T_i} + \vec{p}_{C_i}$ (i)

$(2400)(10) + (1000)(-24)$

$\vec{p}_f = 0$ (f)

The Law of Conservation of Momentum:

In any collision or explosion in a closed system, momentum is conserved. This means that momentum is not created nor destroyed, but only transferred from one object to another.

•the law of conservation of momentum can be written in several ways:

total initial momentum of system = total final momentum of system

$$\vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f}$$

$$\sum \vec{p}_i = \sum \vec{p}_f$$

$$(m_1\vec{v}_1 + m_2\vec{v}_2)_i = (m_1\vec{v}_1 + m_2\vec{v}_2)_f$$

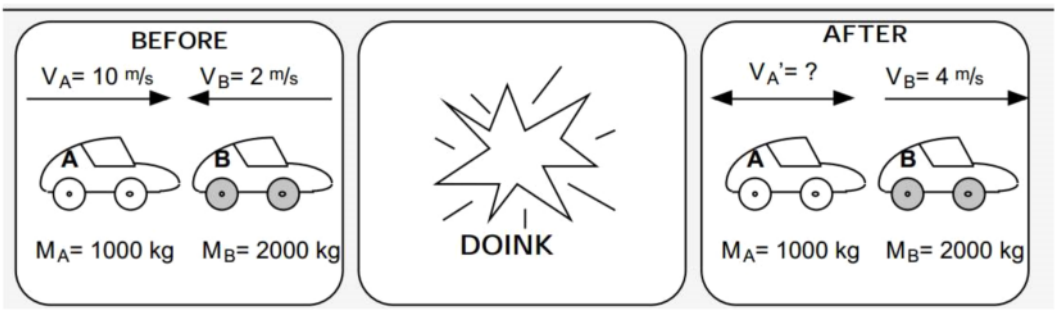
$\sum$ = sigma = "sum of" or "total"

We use the Law of Conservation of Momentum when there is a collision or an explosion.

In short, we use C of M when there is a sion.

Ex. 5) Find the missing velocity (magnitude and direction)

a) i f



$\vec{p} = m\vec{v}$

$\Sigma \vec{p}_i = \Sigma \vec{p}_f$

$\vec{p}_{A_i} + \vec{p}_{B_i} = \vec{p}_{A_f} + \vec{p}_{B_f}$

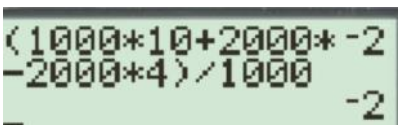
$m_A\vec{v}_{A_i} + m_B\vec{v}_{B_i} = m_A\vec{v}_{A_f} + m_B\vec{v}_{B_f}$

$$\frac{m_A\vec{v}_{A_i} + m_B\vec{v}_{B_i} - m_B\vec{v}_{B_f}}{m_A} = \vec{v}_{A_f}$$

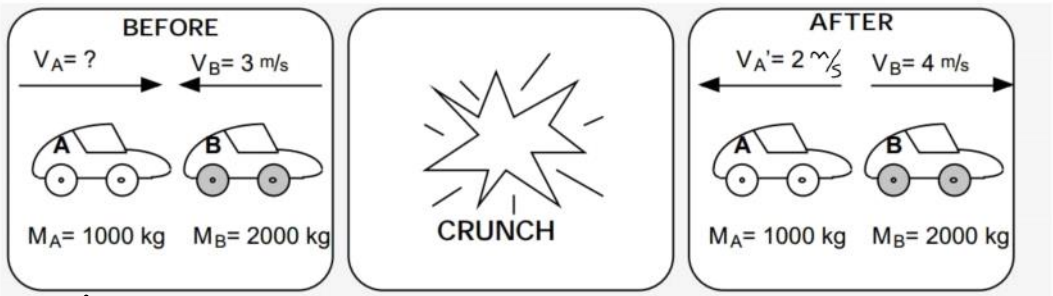
$$\vec{v}_{A_f} = \frac{(1000)(10) + (2000)(-2) - 2000(4)}{1000}$$

$\vec{v}_{A_f} = -2$ m/s

$= 2$ m/s backwards



b)



$$\Sigma \vec{p}_i = \Sigma \vec{p}_f$$

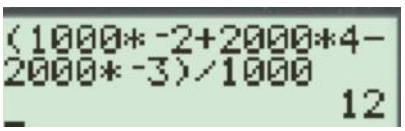
$$\vec{p}_{A_i} + \vec{p}_{B_i} = \vec{p}_{A_f} + \vec{p}_{B_f}$$

$$m_A \vec{v}_{A_i} + m_B \vec{v}_{B_i} = m_A \vec{v}_{A_f} + m_B \vec{v}_{B_f}$$

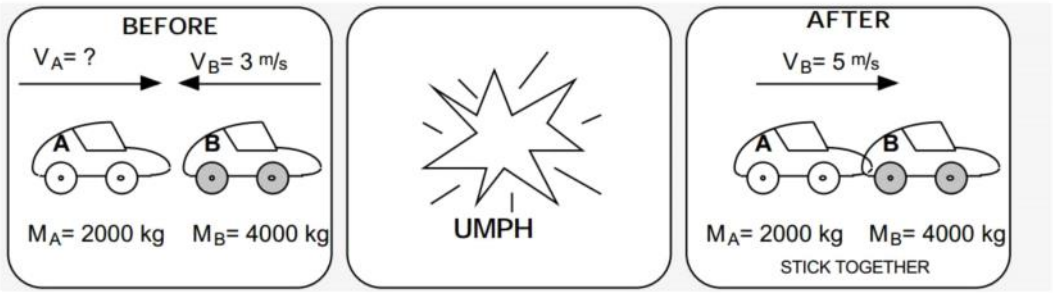
$$\vec{v}_{A_i} = \frac{m_A \vec{v}_{A_f} + m_B \vec{v}_{B_f} - m_B \vec{v}_{B_i}}{m_A}$$

$$\vec{v}_{A_i} = \frac{(1000)(-2) + (2000)(4) - (2000)(-3)}{1000}$$

$$\vec{v}_{A_i} = 12 \text{ m/s forwards}$$



c)



$$\Sigma \vec{p}_i = \Sigma \vec{p}_f$$

$$m_A \vec{v}_{A_i} + m_B \vec{v}_{B_i} = (m_A + m_B)\vec{v}_f$$

$$\vec{v}_{A_i} = \frac{(m_A + m_B)\vec{v}_f - m_B \vec{v}_{B_i}}{m_A}$$

$$\vec{v}_{A_i} = \frac{(2000 + 4000)(5) - 4000(-3)}{2000} = 21 \text{ m/s forwards}$$

d)

$\Sigma \vec{p}_i = \Sigma \vec{p}_f$

$(m_R + m_B)\vec{v}_i = m_R \vec{v}_{R_f} + m_B \vec{v}_{B_f}$

$$\frac{(m_R + m_B)\vec{v}_i - m_R \vec{v}_{R_f}}{m_B} = \vec{v}_{B_f}$$

$$v_{B_f} = \frac{(60+20)(5) - (60)(2)}{20} = 14 \text{ m/s}$$

Lesson 4 Homework:

1. The club head (m=0.170 kg) of a golf club collides with a golf ball (m=0.046 kg) at rest upon a tee.

a. Which object experiences the greatest force?
i) club head ii) golf ball iii) both the same

b. Which object experiences the greatest impulse?
i) club head ii) golf ball iii) both the same

c. Which object experiences the greatest Δ momentum?
i) club head ii) golf ball iii) both the same

d. Which object experiences the greatest acceleration?
i) club head ii) golf ball iii) both the same

Ans: a (iii), b (iii), c (iii), d (ii)

2. A moving cue ball collides head-on with the eight ball that is at rest upon the pool table. Assume the balls have the same mass.

a. Which object experiences the greatest force?
i) cue ball ii) 8-ball iii) both the same

b. Which object experiences the greatest impulse?
i) cue ball ii) 8-ball iii) both the same

c. Which object experiences the greatest Δ momentum?
i) cue ball ii) 8-ball iii) both the same

d. Which object experiences the greatest acceleration?
i) cue ball ii) 8-ball iii) both the same

Ans: a (iii), b (iii), c (iii), d (iii)

3. A large truck and a Volkswagen (VW) beetle have a head-on collision.

a. Which object experiences the greatest force?
i) truck ii) VW iii) both the same

b. Which object experiences the greatest impulse?
i) truck ii) VW iii) both the same

c. Which object experiences the greatest Δ momentum?
i) truck ii) VW iii) both the same

d. Which object experiences the greatest acceleration?
i) truck ii) VW iii) both the same

Ans for question 3: a (iii), b (iii), c (iii), d (ii)

4. Miles Tugo and Ben Travlun are riding in a bus at highway speed on a nice summer day when an unlucky bug splatters onto the windshield. Miles and Ben begin discussing the physics of the situation. Miles suggests that the momentum change of the bug is much greater than that of the bus. After all, argues Miles, there was no noticeable change in the speed of the bus compared to the obvious change in the speed of the bug. Ben disagrees entirely, arguing that both bug and bus encounter the same force, momentum change, and impulse.
Who do you agree with? _____ Support your answer.

(ans: Ben is correct. Why?)

5. Hobbes, the stuffed tiger, has a mass of 31.8 kg. Calvin, the little boy, has a mass of 25.1 kg. In a game of football, Hobbes runs at Calvin at 11 m/s. Calvin is running away from Hobbes (in the same direction as Hobbes) at 8.33 m/s. (a) If the two collide and stick together, what is their final velocity? (b) What impulse is exerted on Hobbes by Calvin? (c) What impulse is exerted on Calvin by Hobbes? (d) If the collision occurred in 0.109 seconds, then what force was exerted on Hobbes? (ans: a) 9.82 m/s forwards, b) -37.45 kg m/s, c) 37.45 kg m/s, d) -344 N)

6. Hobbes, the stuffed tiger, has a mass of 31.8 kg. Calvin, the little boy, has a mass of 25.1 kg. In a game of football, Hobbes runs at Calvin at 7.22 m/s. Calvin is running towards Hobbes. (a) If the two collide, stick together, and are then at rest after the collision, what was Calvin's initial velocity? (b) What impulse is exerted on Hobbes by Calvin? (c) What impulse is exerted on Calvin by Hobbes? (d) If the collision occurred in 0.0600 seconds, then what force was exerted on Hobbes?
(ans: a) -9.15 m/s, b) -230 kg m/s, c) +230 kg m/s, d) -3830 N)

I'll send out a solution key on Wednesday.