Lesson 2 Impulse

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Physics 11 Unit 6 Momentum Name: ___________

Lesson 2 Impulse = change in momentum (Δ)

Prove that change in momentum equals mass times velocity change

Note: "change in" anything = final - initial

$$\Delta \vec{p} \overset{?}{=} m\Delta\vec{v}$$

$$\vec{p}_f - \vec{p}_i = m\vec{v}_f - m\vec{v}_i \quad \text{factor } m$$

$$= m(v_f - v_i) = m\Delta\vec{v}$$

Impulse is defined as change in momentum

Ex. 1) fill in the steps below to find the impulse equation

Take Newton's Second Law: Fnet = ma and solve for acceleration:

$$a = \frac{F}{m}$$

Take the kinematics equation: vf = vi + at and solve for acceleration:

$$a = \frac{v_f - v_i}{t}$$

Setting these two acceleration expressions equal to each other:

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

Then cross-multiply

$$Ft = m\Delta\vec{v}$$

Substitute result from beginning of lesson:

$$\vec{F}t = \Delta\vec{p}$$

• So what this equation signifies is that a force acting for a time will change the amount of motion (momentum) of the system.

net force • time = mass • velocity change = momentum change

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

$$m\Delta\vec{v} \rightarrow m\vec{v}_f - m\vec{v}_i$$

Fnet = net force (N)

m= mass (kg)

Δt= elapsed time (sec)

v_i= initial velocity(m/s)

v_f= final velocity(m/s)

So, you can see that this equation is sort of 3-equations-in-1:

•You may have noticed that we seem to be paying more attention to vector notation than we have been for the last few lessons. This is because in momentum problems there are often changes in direction, and so we need to use precise vector analysis like we did for velocity and acceleration.

Ex 1: A 0.144 kg baseball is pitched horizontally due East at 38 m/s. After it is hit by a bat, it moves horizontally due West at 55 m/s.

(a) What impulse did the bat deliver to the ball?

(b) Where do you think this impulse came from?

(c) If the bat and ball were in contact 0.80 ms, what was the average force the bat exerted on the ball?

(d) Find the average acceleration of the ball during its contact with the bat.

a) $\Delta\vec{p} = m\vec{v}_f - m\vec{v}_i$ or $m\vec{v}_f - m\vec{v}_i$

$\Delta\vec{p} = (.144)(-55) - (.144)(38) = -13.4$ kg m/s

$= 13.4$ kg m/s @ West

b) the bat

c) $t = .80$ ms $= .80 \times 10^{-3}$ s $= .0008$ s

$\Delta\vec{p} = \vec{F}t \Rightarrow \vec{F} = \frac{\Delta\vec{p}}{t} = \frac{-13.392}{.0008} = -16700$ N

or 16700 N @ West

d) $F = ma \rightarrow a = \frac{F}{m} = \frac{-16700}{.144} = -116250$ m/s²

or 116250 m/s² @ West

Ex 2a) What is the momentum of a 112 kg football player running due North with a speed of 3.6 m/s?

$\vec{p} = m\vec{v} = (112)(3.6) = 403.2$ kg m/s @ North

b) What impulse must a tackler impart to the football player to bring him to a stop?

$\Delta\vec{p} = p_f - p_i = 0 - 403.2 = -403.2$ kg m/s

$= 403.2$ kg m/s @ South

c) If the tackle was completed in 0.80 s, what average force did the tackler exert on the other player?

$t = .8$ s

$\Delta\vec{p} = \vec{F}t \rightarrow \vec{F} = \frac{\Delta\vec{p}}{t} = \frac{403.2}{.8} = 504$ N @ South

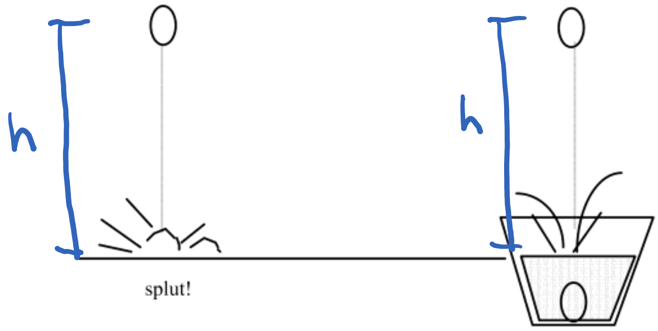
•although we solved the previous problem using impulse, we could really have done it using Newton's second law:

$v_f = v_i + at$

$F_{net} = ma$

so why do we bother with momentum/impulse? Well the main reason is that is the best tool we have to analyze collision problems (next lesson). There are however, a few other questions that are most easily answered using impulse. For instance, consider the following example.

•example 3: two eggs are dropped from a height h. One hits the floor and breaks. The second falls in a pail of water and survives. What is the main reason the second egg survives?



Floor	H_2O
$v_i = 0$	$v_i = 0$
$a = -9.8$	$a = -9.8$
v_f = same	v_f
$\Delta\vec{p}$ = same	= $\Delta\vec{p}$

$\Delta\vec{p} = \vec{F}\Delta t \rightarrow \vec{F} = \frac{\Delta\vec{p}}{t}$

Discuss your answer:

Floor	H_2O
F t	F t

This is why Nerf™ objects don't hurt when they hit you. Although they have mass, and even though the change in momentum (the impulse) is the same as being hit with a hard object of identical mass, the sponge material lengthens the time of collision, decreasing the acceleration, and decreasing the force.

Actually, damage from change in (impulse) momentum isn't caused by ***how much*** momentum is absorbed; it's caused by ***how fast*** change in momentum is absorbed. All of you have gone from 100 km/h to 0.

Where has this occurred?

When leaving the freeway, and driving home

Ex.4) Here is another way to think about the egg question. Why do they use bales of hay to line some racetracks? What is the advantage in being brought to a stop by a bale of hay instead of a brick wall? Explain your answer in terms of impulse and forces.

FIGURE 6.5
If the change in momentum occurs over a long time, the hitting force is small.

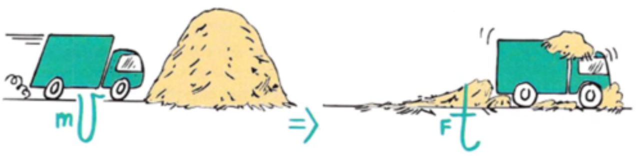
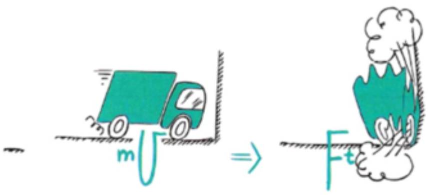


FIGURE 6.6
If the change in momentum occurs over a short time, the hitting force is large.



Ex. 5) In many sports that involve striking something (tennis, baseball, soccer, golf, etc.) players are told to "follow through" when they come in contact with the ball. Why might this help the ball leave with a greater velocity?

$m\Delta\vec{v} = \vec{F}_\Delta t$ as $t\uparrow$, $\Delta\vec{v}\uparrow$

Ex. 6) Which has more momentum, a 1000 kg car moving at 100 km/h or a 2000 kg truck moving at 50 km/h?

They are the same

Ex. 7) Does a moving object have momentum?

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

Ex. 8) Does a moving object have impulse?

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

Not if it's going at a constant velocity

Ex. 9) When you jump from your lab table to the ground, why do you bend your knees as you land?

This is the same as the egg-in-water.
Bending your knees increases time, lowering F.

$\Delta\vec{p} = \vec{F}\Delta t$ OR $\Delta\vec{p} = m\vec{v}_f - m\vec{v}_i$ OR $F\Delta t = m\vec{v}_f - m\vec{v}_i$

↑ N·s

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Lesson 2 Impulse Homework

1. Insert these words into the four blanks of the sentence:
mass, momentum, acceleration, time, impact, weight, impulse, and force.
(Not every word will be used.)
In a collision, an object experiences a(n) ___________________ acting for a certain amount of _____________________ and which is known as a(n) ________________ ; it serves to change the _________________ of the object.

(Ans: force, time, impulse, momentum)

2. A(n) __________________ causes and is equal to a change in momentum.
a. force b. impact c. impulse d. collision Ans: c

3. Calculate the impulse experienced by
a. ... a 65.8-kg halfback encountering a force of 1025 N for 0.350 seconds.

b. ... a 0.168-kg tennis ball encountering a force of 126 N that changes its velocity by 61.8 m/s.

(Ans: 359 N s, 10.4 kg m/s)

4. A force of 20.0 N west is applied to a 3.00 kg object for 4.00 seconds. Calculate the impulse experienced by the object.
(Ans: 80 Ns west)

5. A 1200 kg car traveling at 20.0 m/s north changes speeds to 30.0 m/s south. What is the impulse experienced by the car?
(Ans: 60000 kg m/s South)

6. A 1500 kg car accelerates from 55.0 km/h to 90.0 km/h. Calculate the magnitude of the impulse experienced by the car.
(Ans: 14600 kg m/s)

7.

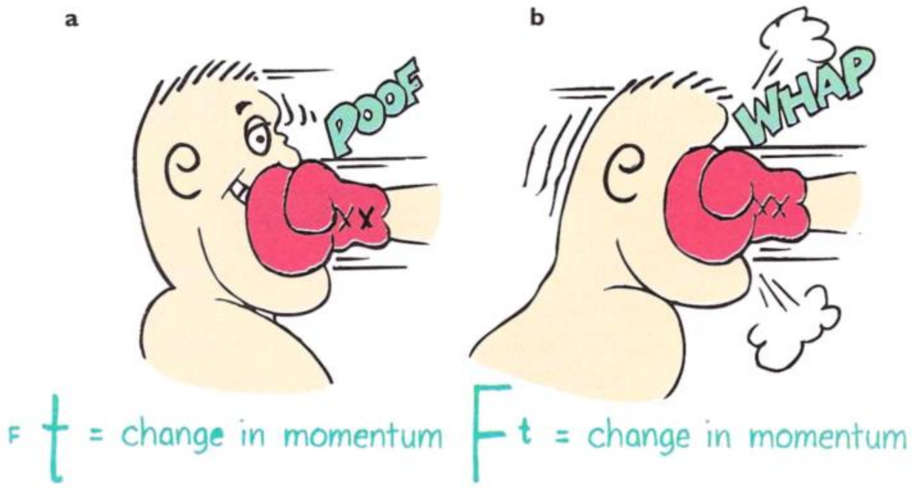

FIGURE 6.8
In both cases, the impulse provided by the boxer's jaw reduces the momentum of the punch. (a) When the boxer moves away (rides with the punch), he extends the time and diminishes the force. (b) If the boxer moves into the glove, the time is reduced and he must withstand a greater force.

a) If the boxer in Figure 6.8 is able to increase the duration of impact three times as long by riding with the punch, by how much will the force of impact be reduced?

b) If the boxer instead moves into the punch such as to decrease the duration of impact by half, by how much will the force of impact be increased?

c) A boxer being hit with a punch contrives to extend time for best results, whereas a karate expert delivers a force in a short time for best results. Isn't there a contradiction here?

(Ans: a. the force will be divided by 3 (so 1/3 as large as before)
b. the force will double
c. No. A karate expert wants the force to be as large as possible (so time of impact is small), and a boxer being hit wants the force to be as small as possible (so time of impact is large))

I'll send out a solution key on Wednesday. I'll also send out another optional "Whoa Wednesday" YouTube assignment.