Momentum, Impulse and Momentum Change

Read from **Lesson 1** of the **Momentum and Collisions** chapter at **The Physics Classroom:**

http://www.physicsclassroom.com/Class/momentum/u4l1a.html
http://www.physicsclassroom.com/Class/momentum/u4l1b.html

MOP Connection: Momentum and Collisions: sublevels 1 and 2

Momentum

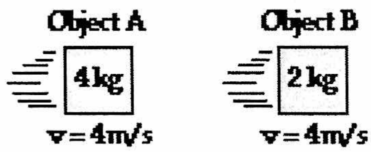
1. The momentum of an object depends upon the object's ________. Pick two quantities.
   (a) mass - how much *stuff* it has
   b. acceleration - the rate at which *the stuff* changes its velocity
   c. weight - the force by which gravity attracts *the stuff* to Earth
   (d) velocity - how fast and in what direction it's *stuff* is moving
   e. position - where the *stuff* is at

2. Momentum is a ___________ quantity.
   a. scalar (b) vector

3. Which are **complete** descriptions of the momentum of an object? Circle all that apply.
   a. 2.0 kg/s (b) 7.2 kg•m/s, right c. 6.1 kg•m/s², down
   d. 4.2 m/s, east (e.) 1.9 kg•m/s, west (f.) 2.3 kg•m/s ← +ive & -ive DIRECTION

4. The two quantities needed to calculate an object's momentum are MASS and VELOCITY.

5. Consider the mass and velocity values of Objects A and B below. Compared to Object B, Object A has ____ momentum.
   (a) two times the b. four times the
   c. eight times the d. the same
   e. one-half the f. one-fourth the
   g. ... impossible to tell without knowledge of the F and a.



6. Calculate the momentum value of .... (Include appropriate units on your answers.)
   a. ... a 2.0-kg brick moving through the air at 12 m/s.

   $p = m\vec{v} = (2.0\,kg)(12\,m/s) = 24\ kg\cdot m/s$

   b. ... a 3.5-kg wagon moving along the sidewalk at 1.2 m/s.

   $p = m\vec{v} = (3.5\,kg)(1.2\,m/s) = 4.2\ kg\cdot m/s$

7. With what velocity must a 0.53-kg softball be moving to equal the momentum of a 0.31-kg baseball moving at 21 m/s?

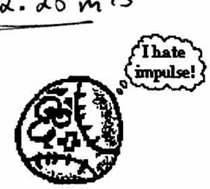
   $p = (0.31\,kg)(21\,m/s) = 6.51\ kg\cdot m/s$

   $p = m\vec{v}$

   $\vec{v} = \frac{p}{m} = \frac{6.51\ kg\cdot m/s}{0.53\ kg} = 12.28\ m/s$

Impulse and Momentum Change

8. 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) FORCE acting for a certain amount of TIME and which is known as a(n) IMPULSE; it serves to change the MOMENTUM of the object.

9. A(n) IMPULSE causes and is equal to a change in momentum.
   a. force   b. impact   c. impulse   d. collision

10. Calculate the impulse experienced by ..... (Show appropriate units on your answer.)
   a. ... a 65.8-kg halfback encountering a force of 1025 N for 0.350 seconds.

   $I = Ft = (1025\ N)(0.350\ s) = 359\ N\cdot s$

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

   $\Delta p = I$ $\Delta p = (0.168\ kg)(61.8\ m/s) = 10.4\ kg\cdot m/s$ $I = 10.4\ N\cdot s$

11. Determine the impulse (I), momentum change (Δp), momentum (p) and other values.

A 7-ball collides with the 8-ball.

I = −0.3 N·s

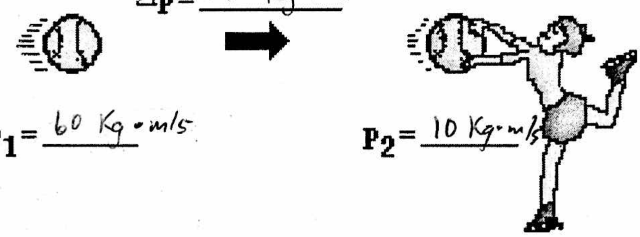
Δp = − 0.3 kg·m/s

m = 0.1 kg, v = 4 m/s → m = 0.1 kg, v = 1 m/s

P_1 = 0.4 kg·m/s P_2 = 0.1 kg·m/s

A moving medicine ball is caught by a girl on ice skates.

m = 10 kg, v = 6 m/s   I = -50 N·s   Δp = −50 kg·m/s   m = 10 kg, v = 1 m/s



P_1 = 60 kg·m/s P_2 = 10 kg·m/s

A car is at rest when it experiences a forward propulsion force to set it in motion. It then experiences a second forward propulsion force to speed it up even more. Finally, it brakes to a stop.

I = 16 000 N   I = 18 000 N·s   I = − 34 000 N·s

Δp = 16 000 kg·m/s   Δp = 18 000 kg·m/s   Δp = − 34 000 kg·m/s

At rest F_{app} = 4000 N, t = 4.0 s F_{app} = 6000 N, t = 3.0 s F_{frict} = 8000 N, t = 4.25 s   Stopped

P_1 = 0 P_2 = 16 000 kg·m/s P_3 = 34 000 kg·m/s P_4 = 0

A tennis ball is at rest when it experiences a forward force to set it in motion. It then strikes a wall where it encounters a force that slows it down and finally turns it around and sends it backwards.

I = 6 N·s, R   I = 6 N·s, L   I = 4.8 N·s, L

Δp = 6 kg·m/s, R   Δp = 6 kg·m/s, L   Δp = 4.8 kg·m/s, L

F_{app} = 60 N, R F_{wall} = 120 N, L F_{wall} = 120 N

Stopped   t = 0.1 s   Moving Right   t = 0.05 s   v = 0 m/s   t = 0.04 s   Moving Left

P_1 = 0 P_2 = 6 kg·m/s, R P_3 = 0 P_4 = 4.8 kg·m/s, L

Controlling a Collision

Read from **Lesson 1** of the **Momentum and Collisions** chapter at **The Physics Classroom:**

http://www.physicsclassroom.com/Class/momentum/u4l1a.html
http://www.physicsclassroom.com/Class/momentum/u4l1b.html

MOP Connection: Momentum and Collisions: sublevel 3

Review:

1. A halfback (m = 80 kg), a tight end (m = 100 kg), and a lineman (m = 120 kg) are running down the football field. Consider their ticker tape patterns below.

Lineman → •

Tight End → • • • • • • • • • • • • • • • •

Halfback → • • • • • • • • • • • •

The lineman's velocity is 3 m/s (right). The tight end's velocity is __6__ m/s and the halfback's velocity is __9__ m/s. Which player has the greatest momentum and how much momentum does he have? __HALFBACK__ Explain.

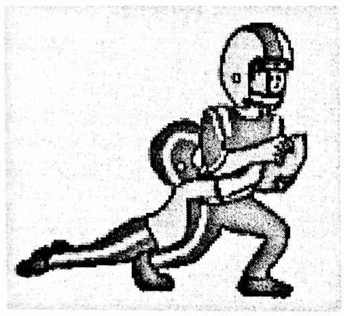
$p_L = (120\ kg)(3\ m/s) = 360\ kg\cdot m/s$ $p_T = (100\ kg)(6\ m/s) = 600\ kg\cdot m/s$
$p_H = (80\ kg)(9\ m/s) = 720\ kg\cdot m/s$

2. A football fullback is running down the field at constant speed until he encounters a defensive back. The dot diagram depicts the motion of the fullback.

• •••

↑

Indicate on the dot diagram (by means of an arrow) the approximate location at which the fullback-defensive back collision occurs.



Which direction (right or left) does the force upon the fullback act? __LEFT__ Explain how you know.

SLOWS DOWN ∴ FORCE & AS A RESULT $\vec{a}$ MUST BE OPPOSITE MOTION

What happens to the momentum of the fullback upon colliding with the defensive back?

IT DECREASES AS $\vec{v}$ DECREASES

Using the F•t = m•Δv Equation to Analyze Impulses and Momentum Changes:

3. Two cars of equal mass are traveling down Lake Avenue with equal velocities. They both come to a stop over different lengths of time. The dot diagrams for each car are shown below.

Car A . . . .

Car B . . . .

Which car (A or B) experiences the greatest acceleration? __A__ Explain.

Which car (A or B) experiences the greatest change in momentum? __SAME__ Explain.

Which car (A or B) experiences the greatest impulse? __SAME__ Explain.

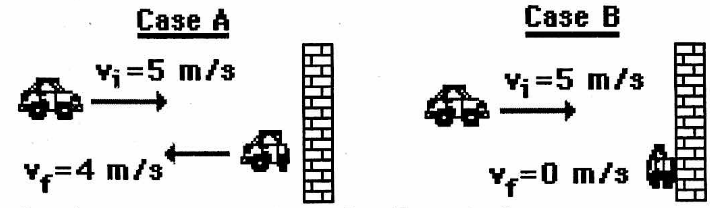
Which car (A or B) experiences the greatest force? __A__ Explain.

DOT'S SAME DISTANCE INITIALLY = SAME $\vec{V}_i$ = SAME Δ MOMENTUM AS BOTH COME TO STOP. A HOWEVER STOPS IN LESS TIME AND THUS WOULD HAVE A GREATER F & $\vec{a}$

4. When a boxer recognizes that he/she will be hit by an opposing fist, he/she rides the punch. Use physics to explain why. Δ MOMENTUM IS SAME IN BOTH CASES (FIST COMES TO STOP), RIDING THE PUNCH ↑ TIME OVER W/C THE ΔMOMENTUM OCCURS, ∴ ↓ F & $\vec{a}$

5. Mountain climbers use nylon safety ropes due to their tendency to stretch considerably under stress. Use physics to explain why.
↑ TIME OVER W/C THE ΔMOMENTUM OCCURS, ∴ ↓ F & $\vec{a}$ ON CLIMBER IF THEY FALL

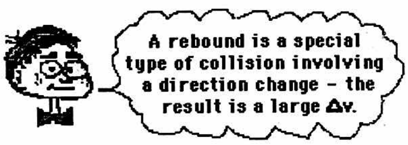
Consider the diagram at the right for the next three questions. The diagram depicts **Before** and **After** velocities of an 800-kg car in two different collisions with a wall. In case A, the car rebounds upon collision. In case B, the car hits the wall, crumples up and stops. Assume that the collision time for each collision is the same.



_________ 6. In which case does the car experience the greatest momentum change?
(a.) Case A b. Case B c. Both the same d. Insufficient information

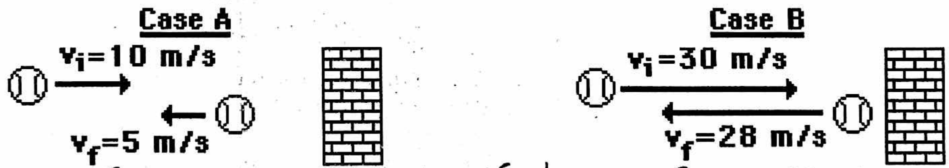
_________ 7. In which case does the car experience the greatest impulse?
(a.) Case A b. Case B c. Both the same d. Insufficient information

_________ 8. The impulse encountered by the 800-kg car in case A has a magnitude of ___ N•s.
a. 0 b. 800 c. 3200 d. 4000
(e.) 7200 f. Not enough information to determine.



9. Evaluate the potential hazard to a passenger involved in a head-on collision in which the two cars stick together compared to when they rebound upon impact. Explain.
REBOUND CAUSES A GREATER ΔMOMENTUM AND IF TIME OVER W/C FORCE IS APPLIED IS THE SAME, THE FORCE EXPERIENCED WILL BE ↑

10. The diagram below depicts the changes in velocity of a ball that undergoes a collision with a wall. Indicate which case (A or B) has the greatest change in velocity, greatest acceleration, greatest momentum change, and greatest impulse. Support each answer.



Greatest Δv? __B__ Explanation: A: −15 m/s B: −58 m/s
Greatest a? __B__ Explanation: GREATER $\Delta\vec{v}$ IN SAME TIME = ↑ $\vec{a}$
Greatest Δp? __B__ Explanation: GREATER $\Delta\vec{v}$ = GREATER Δp (SAME MASS)
Greatest FΔt? __B__ Explanation: I = Δp

Simple Computations with Impulse = Momentum Change

Read from **Lesson 1** of the **Momentum and Collisions** chapter at **The Physics Classroom:**

http://www.physicsclassroom.com/Class/momentum/u4l1b.html
http://www.physicsclassroom.com/Class/momentum/u4l1c.html

A car with a mass of 1000 kg is at rest at a stoplight. When the light turns green, it is pushed by a net force of 2000 N for 10 s.

1. What is the value of the **acceleration** that the car experiences?

$F_{NET} = m\vec{a}$ $\vec{a} = \frac{F_{NET}}{m} = \frac{2000\,N}{1000\,Kg} = 2\,m/s^2$

2. What is the value of the **change in velocity** that the car experiences?

$\vec{a} = \frac{\Delta\vec{v}}{t}$ $\Delta\vec{v} = \vec{a}t = (2\,m/s^2)(10\,s) = 20\,m/s$

3. What is the value of the **impulse** on the car?

$I = Ft = (2000\,N)(10\,s) = 20\,000\,N\cdot s$

4. What is the value of the **change in momentum** that the car experiences?

$\Delta p = 20000\,Kg\cdot m/s$

5. What is the **final velocity** of the car at the end of 10 seconds?

$20\,m/s$

The car continues at this speed for a while.

6. What is the value of the change in momentum the car experiences as it continues at this velocity?

$0\,Kg\cdot m/s$

7. What is the value of the impulse on the car as it continues at this velocity?

$0\,N\cdot s$

The brakes are applied to the car, causing it to come to rest in 4 s.

8. What is the value of the **change in momentum** that the car experiences?

$\Delta p = -20\,000\,Kg\cdot m/s$

9. What is the value of the **impulse** on the car?

$I = -20000\,N\cdot s$

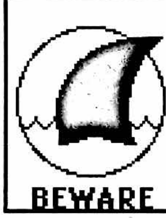
10. What is the value of the **force** (average) that causes the car to stop?

$I = Ft$ $F = \frac{I}{t} = \frac{-20\,000\,N\cdot s}{4\,s} = -5000\,N$

11. What is the **acceleration** of the car as it stops?

$F = m\vec{a}$ $\vec{a} = \frac{F}{m} = \frac{-5000\,N}{1000\,Kg} = -5\,m/s^2$

NOTE: MULTIPLE "WAYS" TO SOLVE
↳ SEE #14 & #16



There is a disease known as *formula fixation* that is common among physics students. It particularly infects those who perceive physics as an applied math course where numbers and equations are simply combined to solve algebra problems. However, this is **not** the true nature of physics. Physics concerns itself with ideas and concepts that provide a reasonable explanation of the physical world. When students divorce the mathematics from the ideas, formula fixation takes root and even mathematical problem solving can become difficult. Do you have *formula fixation*? Test your health by trying these computational problems.

12. A force of 800 N causes an 80-kg fullback to change his velocity by 10 m/s. Determine the impulse experienced by the fullback. **PSYW**

$I = \Delta p$ $\Delta p = m\Delta\vec{v} = (80\,kg)(10\,m/s) = 800\ kg\cdot m/s$

$I = 800\ N\cdot s$

13. A 0.80-kg soccer ball experiences an impulse of 25 N•s. Determine the momentum change of the soccer ball. **PSYW**

$I = \Delta p$ $\Delta p = 25\ kg\cdot m/s$

14. A 1200-kg car is brought from 25 m/s to 10 m/s over a time period of 5.0 seconds. Determine the force experienced by the car. **PSYW**

$\vec{a} = \frac{\Delta\vec{v}}{t} = \frac{-15\,m/s}{5\,s} = -3\ m/s^2$ $F = ma$

$F = (1200\,kg)(-3\,m/s^2) = -3600\,N$

15. A 90-kg tight end moving at 9.0 m/s encounters a 400 N•s impulse. Determine the velocity change of the tight end. **PSYW**

$I = \Delta p$

$I = m\Delta\vec{v}$ $\Delta\vec{v} = \frac{I}{m} = \frac{400\ N\cdot s}{90\,kg} = 4.4\bar{4}\ m/s$

16. A 0.10-kg hockey puck decreases its speed from 40 m/s to 0 m/s in 0.025 s. Determine the force that it experiences. **PSYW**

$I = \Delta p$

$Ft = m\Delta\vec{v}$ $F = \frac{m\Delta\vec{v}}{t} = \frac{(0.10\,kg)(-40\,m/s)}{0.025\,s} = -160\ N$

17. **A Real Brain Twister:** A 0.10-kg hockey puck is at rest. It encounters a force of 20 N for 0.2 seconds that sets it into motion. Over the next 2.0 seconds, it encounters 0.4 Newtons of resistance force. Finally, it encounters a final force of 24 N for 0.05 seconds in the direction of motion. What is the final velocity of the hockey puck? **PSYW**

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

$\Delta\vec{v}_1 = \frac{Ft}{m} = \frac{(20\,N)(0.2\,s)}{(0.1\,kg)} = 40\,m/s$

$\Delta\vec{v}_2 = \frac{(-0.4\,N)(2\,s)}{0.1\,kg} = -8\,m/s$

$\Delta\vec{v}_3 = \frac{(24\,N)(0.05\,s)}{0.1\,kg} = 12\,m/s$

$v_f = 40\,m/s - 8\,m/s + 12\,m/s = 44\ m/s$

You may have been *tricked*, but those were not intended as trick questions. The questions were intended to test your understanding of the concepts of momentum change, impulse, mass, force, time and velocity change. How is your understanding level progressing? Do you have formula fixation?