Momentum and Impulse

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Momentum and Impulse

Momentum is the quantity that Sir Isaac Newton actually spoke about. It is the product of mass and velocity.

$$p = mv = Kg \times \left(\frac{m}{s}\right)$$

A big and slow thing can hit you with the same momentum as a small and quick thing.

This is a .50 cal sniper rifle. It launches bullets of mass 50g at a velocity of 850m/s. This would impact a watermelon with a momentum of 42.5kg*m/s!

This is the same as being hit with a 1kg bag of sugar at 153km/hr!

Example:

Taylor was embarrassed over Spring Break because he was going to be late for the physics party. Taylor weighs 60kg, and ran at 6.0m/s to get there. What was Taylor's momentum?

$$p = (60)(6)$$
$$= 360 \ \frac{Kg \cdot m}{s}$$

As velocity is a vector, so is momentum. A vector multiplied by a scalar is still a vector.

What has the bigger momentum a truck or the dog chasing it?

What about when the truck stops?

If we apply a force for a time, we change the momentum.

To find the change in momentum, like with other things we need to change in, we find the final value and subtract the initial value.

$$\Delta p = m(v_f - v_i)$$

$$\Delta p = m\Delta v$$

However, we also know that;

$$m\Delta v = at\, m = mat$$

$$m\Delta v = \Delta p = F \cdot t = \text{impulse}$$

You need to remember that;

$$\Delta p = Ft = \text{impulse}$$

Example:

Nolan is wide open in front of the net. His teammate passes him the puck (170g) at a velocity of 6.6m/s. Nolan takes a big shot and hits the puck with 50N of force. The time for the impact was 0.25s. What is the velocity of the shot? (67m/s)

$\Delta p = mv$

$F \cdot t = m(v_f - v_i)$

$50(.25) = 170 \times 10^{-3}(v_f - (-6.6))$

$\frac{50(.25)}{170 \times 10^{-3}} - 6.6 = v_f$

What is the change in momentum of the puck?

$\Delta p = F \cdot t = \text{impulse}$ $\qquad F \cdot t = N \cdot s$

$m(v_f - v_i) = F \cdot t$

$170 \times 10^{-3}(67 - (-6.6)) = 50(.25)$

$12.5 \frac{kg \cdot m}{s} = 12.5 \frac{kg \cdot m}{s}$

Example:

Imagine throwing a 5.0kg ball into a wall at 10m/s. If the ball bounces off at 10m/s towards you. What was the change in momentum?

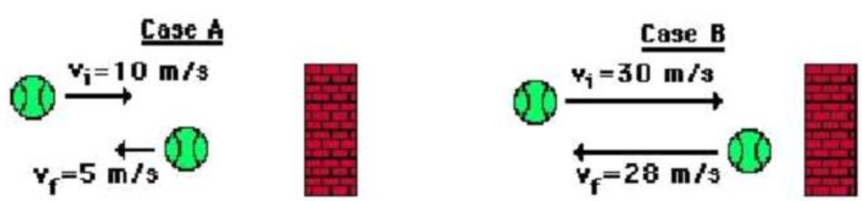
$\Delta p = m \Delta v$

$= m(v_f - v_i)$

$= 5(-10 - 10)$

$= 5(-20)$

$= -100\ N \cdot s$



$\Delta \rightarrow \text{final} - \text{initial}$

$V_f - V_i$

A) -5 - 10 = -15

B -28 - 30 = -58

	A	B
Greatest Δv		✓
Greatest Δa		✓
Greatest Δp		✓
Greatest ΔI		✓

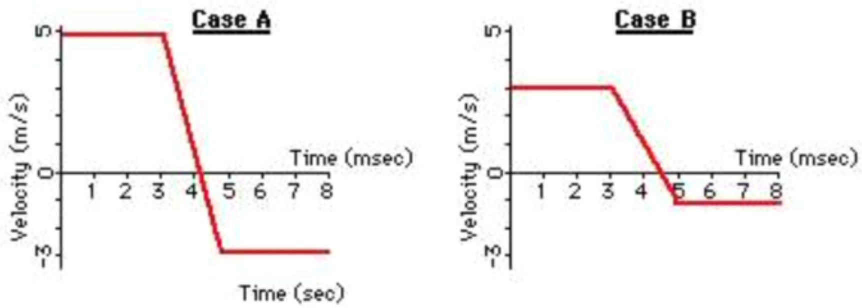
MOMENTUM LESSON

1. Determine the momentum of a …
    a. 60-kg halfback moving eastward at 9 m/s.
    b. 1000-kg car moving northward at 20 m/s.
    c. 40-kg freshman moving southward at 2 m/s.

2. 2. A car possesses 20 000 units of momentum. What would be the car's new momentum if …
    a. its velocity were doubled.
    b. its velocity were tripled.
    c. its mass were doubled (by adding more passengers and a greater load)
    d. both its velocity were doubled and its mass were doubled.

3. A halfback (m = 60 kg), a tight end (m = 90 kg), and a
4. Which case (A or B) has the greatest change in velocity, greatest **acceleration**, greatest **momentum** change, and greatest **impulse**.

Velocity-Time Graph



5. Which case (A or B) has the greatest change in velocity, greatest <u>acceleration</u>, greatest <u>momentum</u> change, and greatest <u>impulse</u>.

<u>Ticker Tape Diagram</u>

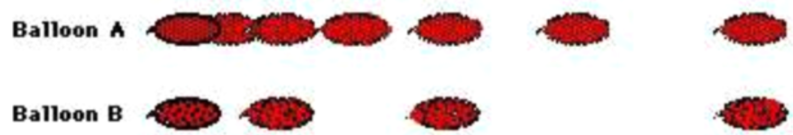
6. Use the impulse-momentum change principle to fill in the blanks in the following rows of the table. As you do, keep these three major truths in mind:
   a. the impulse experienced by an object is the force•time
   b. the momentum change of an object is the mass•velocity change
   c. the impulse equals the momentum change

	Force (N)	time (s)	Impulse (N*s)	Mom. Change (kg*m/s)	Mass (kg)	Vel. Change (m/s)
1.		0.010			10	-4
2.		0.100	-40		10	
3.		0.010		-200	50	
4.	-20 000			-200		-8
5.	-200	1.0			50	

7. 7. A 0.50-kg cart (#1) is pulled with a 1.0-N force for 1 second; another 0.50 kg cart (#2) is pulled with a 2.0 N-force for 0.50 seconds. Which cart (#1 or #2) has the greatest acceleration? Explain.
   a. Which cart (#1 or #2) has the greatest impulse? Explain.

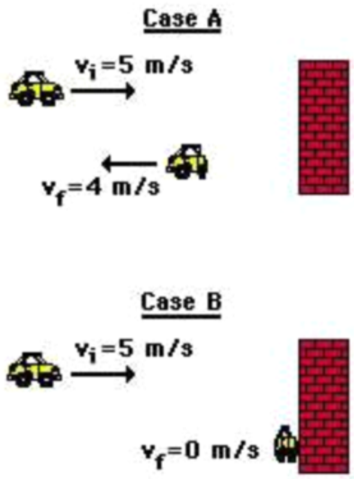
b. Which cart (#1 or #2) has the greatest change in momentum? Explain.

8. In a physics demonstration, two identical balloons (A and B) are propelled across the room on horizontal guide wires. The motion diagrams (depicting the relative position of the balloons at time intervals of 0.05 seconds) for these two balloons are shown below.



a. Which balloon (A or B) has the greatest acceleration? Explain.
b. Which balloon (A or B) has the greatest final velocity? Explain.
c. Which balloon (A or B) has the greatest momentum change? Explain.
d. Which balloon (A or B) experiences the greatest impulse? Explain.

9. The diagram to the right depicts the before- and after-collision speeds of a car which undergoes a head-on-collision with a wall. In Case A, the car bounces off the wall. In Case B, the car crumples up and *sticks* to the wall.
   a. In which case (A or B) is the change in velocity the greatest? Explain.
   b. In which case (A or B) is the change in momentum the greatest? Explain.
   c. In which case (A or B) is the impulse the greatest? Explain.
   d. In which case (A or B) is the force which acts upon the car the greatest (assume contact times are the same in both cases)? Explain.



10. Kenzie, who has a mass of 50.0 kg, is riding at 35.0 m/s in her red sports car when she must suddenly slam on the brakes to avoid hitting a deer crossing the road. She strikes the air bag, which brings her body to a stop in 0.500s. What average force does the seat belt exert on her?

11. If Kenzie had <u>not</u> been wearing her seat belt and not had an airbag, then the windshield would have stopped her head in 0.002 s. What average force would the windshield have exerted on her?
    Note that a 250-fold decrease in the time corresponds to a 250-fold increase in the force.

12. A Nolan applies an average force of 80.0 N to a 0.25 kg hockey puck for a time of 0.10 seconds. Determine the impulse experienced by the hockey puck.

13. If a 5.0-kg object experiences a 10.0-N force for a duration of 0.10-second, then what is the momentum change of the object?