Momentum and Impulse

Hand-In Experiment #9

Momentum and Impulse

Momentum

- A team is said to have **Momentum** if they are "on a roll," or "hard to stop."
- In Physics, momentum is a **vector quantity** that describes the **motion of mass**.
- Any **moving body** has momentum



Momentum

- **An object's momentum depends on its mass and how fast it is moving.**

*A truck traveling 5 km/h has more momentum than a Smart car at the same speed because **it is harder to stop**.*

Momentum and Inertia

- **Inertia is a tendency for an object to keep doing what it's doing.**
- **The "momentum" of an object is the quantification of its Inertia or how difficult it is to stop its inertial movement.**

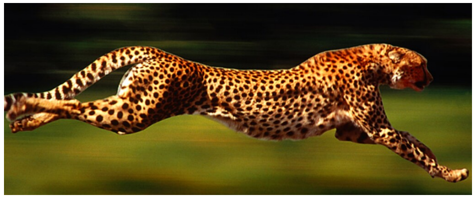
Momentum

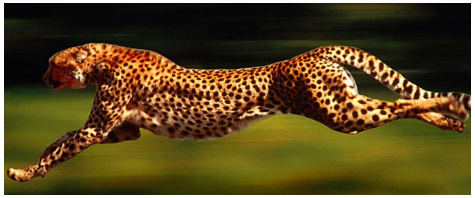
The momentum of any object can be calculated by:

$$p = m\Delta v$$

- ***m*** **is the mass in** ***kg***
- ***v*** **is the change in velocity in** ***m/s – NEED A REFERENCE FRAME***
- ***p is momentum (kg·m/s OR N·s)***

Momentum is a vector quantity – so direction IS important!





Linear Momentum

Example #1

Determine the momentum of a Pacific leatherback turtle that has a mass of mass 860 kg, swimming east at a velocity of 1.3 m/s.

1,118 kg·m/s east

Linear Momentum

Example #2

A 588 N halfback is moving at 9 m/s towards the end zone. What is their momentum?

539.46 kg·m/s towards the end zone

Impulse

Will it break?

From Newton's 2nd Law

Impulse-Momentum Theorem Formula

Impulse

- A force acting for a given amount of time to change an object's momentum.
- Its direction is the same as the change in momentum

Impulse

- Impulse: $J = F \cdot \Delta t$
- Units: $N \cdot s$
- Is equal to an object's change in momentum
- If you increase Δt, F will decrease
- If you are trying to catch a ball and you move your hands back with the ball as it approaches, you will increase the time needed to stop the momentum and thus, decrease the F required → hurts less!

Impulse

The same principle explains why dashboards are padded. If the air bags do not deploy (or are not installed in a car), then the driver and passengers run the risk of stopping their momentum by means of a collision with the windshield or the dashboard.

If the driver or passenger should hit the dashboard, then the force and time required to stop their momentum is exerted by the dashboard. Padded dashboards provide some give in such a collision and serve to extend the time duration of the impact, thus minimizing the effect of the force.

This same principle of padding a potential impact area can be observed in gymnasiums (underneath the basketball hoops), in pole-vaulting pits, in baseball gloves and goalie mitts, on the fist of a boxer, inside the helmet of a football player, and on gymnastic mats. Now that's physics in action.

Momentum and Impulse

Example #3

You are driving in a car which has a mass of 1,000 kg and is traveling at 30 km/h. You lose control and it smashes into a concrete wall essentially stopping the momentum of your car in 0.10 s.

a. What is the momentum of your car at impact?
b. What Force is required to stop the car?
c. If you hit a padded wall instead which brings the car to a stop in 0.50 s, what Force will be required?
d. What is the purpose of airbags with respect to momentum and impulse?

Momentum and Impulse

Example #3 (Answers)

a. 8,330 kg·m/s
b. 83,300 N
c. 16,660 N
d. They increase the time required to stop the momentum (motion) of your head thus decreasing the force needed to do so.

The importance of follow through

The importance of follow through

In racket and bat sports, hitters are often encouraged to follow-through when striking a ball. High-speed films of the collisions between bats/ rackets and balls have shown that the act of following through serves to increase the time over which a collision occurs.
This increase in time must result in a change in some other variable in the impulse-momentum change theorem. Surprisingly, the variable that is dependent upon the time in such a situation is not the force.
The force in hitting is dependent upon how *hard* the hitter swings the bat or racket, not the time of impact. Instead, the follow-through increases the time of collision and subsequently contributes to an increase in the velocity change of the ball.
By following through, a hitter can hit the ball in such a way that it leaves the bat or racket with more velocity (i.e., the ball is moving faster). In tennis, baseball, racket ball, etc., giving the ball a high velocity often leads to greater success. Now that's physics in action.

What is their function?

Momentum and Impulse

Example #4

A baseball of mass 0.152 kg, travelling horizontally at 37.5 m/s east, collides with a baseball bat. The collision lasts for .00115 s. Immediately after the collision, the baseball travels horizontally at 49.5 m/s west.

a. **Determine the change in momentum of the baseball.**
b. **What is the average force applied by the bat to the baseball?**

- a. **13.22 kg·m/s west**
- b. **11,500 N west**

Momentum and Impulse

Example #5

A 57 g tennis ball is thrown upward and then struck just as it comes to rest at the top of its motion. The racket exerts an average horizontal force of magnitude 420 N on the tennis ball.

a. Determine the speed of the ball after the collision if the average force is exerted on the ball for 0.0045 s.
b. Repeat the calculation assuming a time interval of 0.0053 s (Extended follow-through).
c. Explain the meaning and advantage of follow-through in this example.

a. V_f = 33.16 m/s
b. V_f = 39.05 m/s
c. The follow through increase the time the force is in contact with the object and therefore increases the momentum. Since the mass is fixed, the velocity increases.

Momentum and Impulse

Example #6

A force of 6 N acts on a 4-kg object for 10 seconds.

a. What is the object's change in momentum?
b. What is its change in velocity?

a. 60 N·s
b. 15 m/s

Momentum and Impulse

Example #7

What is the final speed of a 20,000 kg rocket which is traveling at 100 m/s and then has a 200,000 N force acting on it for 15 seconds?

250 m/s