Impulse & Momentum

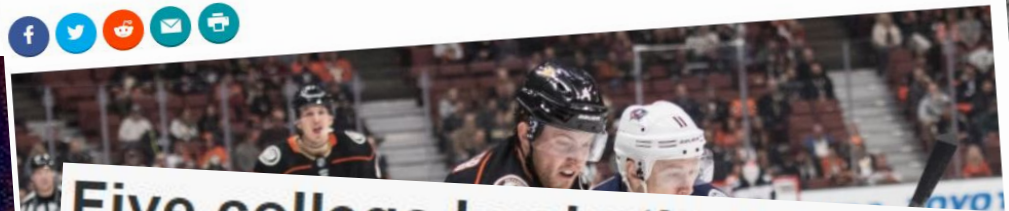
Concept Summary

Boone County High School Physics

Towson men's lacrosse swings momentum late in 8-6 victory over UMBC

Momentum Swings in Favor of Design-Build Legislation

Ducks creating momentum swings by killing penalties



Five college basketball teams with momentum entering March

Scott Gleeson, USA TODAY Sports Published 4:36 p.m. ET March 1, 2017

Momentum

- Momentum is what Newton called the "***quantity of motion***" of an object.

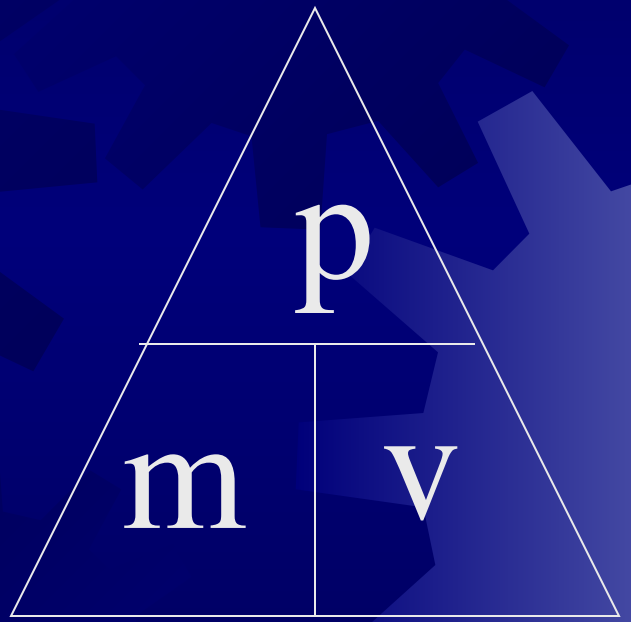
Momentum

- The ***momentum*** of an object:
- Depends on the object's ***mass***.
  - Momentum is ***directly proportional*** to mass.
- Depends on the object's ***velocity***.
  - Momentum is ***directly proportional*** to velocity.

Momentum

- In symbols:

$$p = mv$$



Momentum

- Momentum is a ***vector*** quantity.
- Common units of momentum: kg m/s

Questions

Express your understanding of the concept and mathematics of momentum by answering the following questions. Click the button to view the answers.

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. A car possesses 20 000 units of momentum. What would be the car's new momentum if ...

   a. its velocity was doubled.

   b. its velocity was tripled.

   c. its mass was doubled (by adding more passengers and a greater load)

   d. both its velocity was doubled and its mass was doubled.

Questions

2. Which of the following are true about the relationship between momentum end energy?

a. Momentum is a form of energy.
b. If an object has momentum, then it must also have mechanical energy.
c. If an object does not have momentum, then it definitely does not have mechanical energy either.
d. Object A has more momentum than object B. Therefore, object A will also have more kinetic energy.
e. Two objects of varying mass have the same momentum. The least massive of the two objects will have the greatest kinetic energy.

Answers

Answer: BE

a. **FALSE** - No. Momentum is momentum and energy is energy. Momentum is **NOT** a form of energy; it is simply a quantity which proves to be useful in the analysis of situations involving forces and impulses.

b. **TRUE** - If an object has momentum, then it is moving. If it is moving, then it has kinetic energy. And if an object has kinetic energy, then it definitely has mechanical energy.

c. **FALSE** - If an object does NOT have momentum, then it definitely does **NOT** have kinetic energy. However, it could have some potential energy and thus have mechanical energy.

d. **FALSE** - Consider Object A with a mass of 10 kg and a velocity of 3 m/s. And consider Object B with a mass of 2 kg and a velocity of 10 m/s. Object A clearly has more momentum. However, Object B has the greatest kinetic energy. The kinetic energy of A is 45 J and the kinetic energy of B is 100 J.

e. **TRUE** - When comparing the momentum of two objects to each other, one must consider both mass and velocity; both are of equal importance when determining the momentum value of an object. When comparing the kinetic energy of two objects, the velocity of an object is of double importance. So if two objects of different mass have the same momentum, then the object with the least mass has a greater velocity. This greater velocity will tip the scales in favor of the least massive object when a kinetic energy comparison is made.

Impulse

Impulse

- Change in momentum caused by a force applied over a unit time

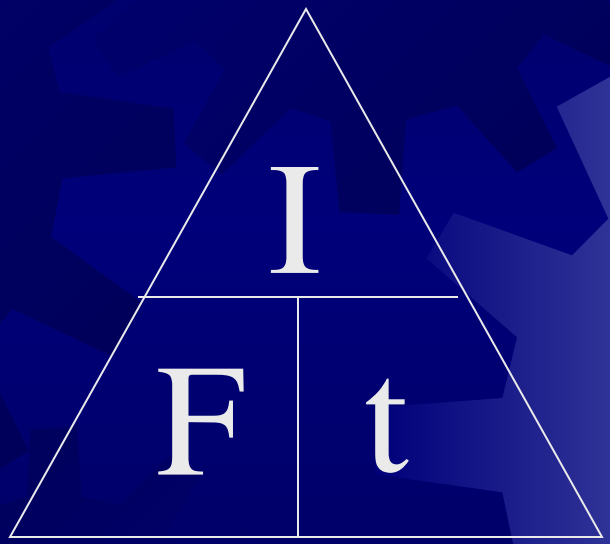
Impulse

- The ***impulse*** exerted on an object depends on:
- The ***force*** acting on the object.
  - Impulse is ***directly proportional*** to force.
- The ***time*** that the force acts.
  - Impulse is ***directly proportional*** to time.

Impulse

- In symbols:

$$I = Ft$$



Impulse

- Impulse is a ***vector*** quantity.
- Common units of impulse: N s

Impulse & Momentum

- The ***impulse*** exerted on an object ***equals*** the object's ***change in momentum.***

Impulse-Momentum Theorem

- In symbols:

$$I = \Delta p$$

or

$$Ft = m\Delta v$$

Instances When I Will Use This…

- Getting the largest possible velocity
- Getting the smallest possible force

Question

- A force of 30 N is exerted for 4 seconds on a 90 kg object.
- A) What is the impulse?
- B) What is the change in momentum?
- C) What is the change in velocity?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C250 40 km/h
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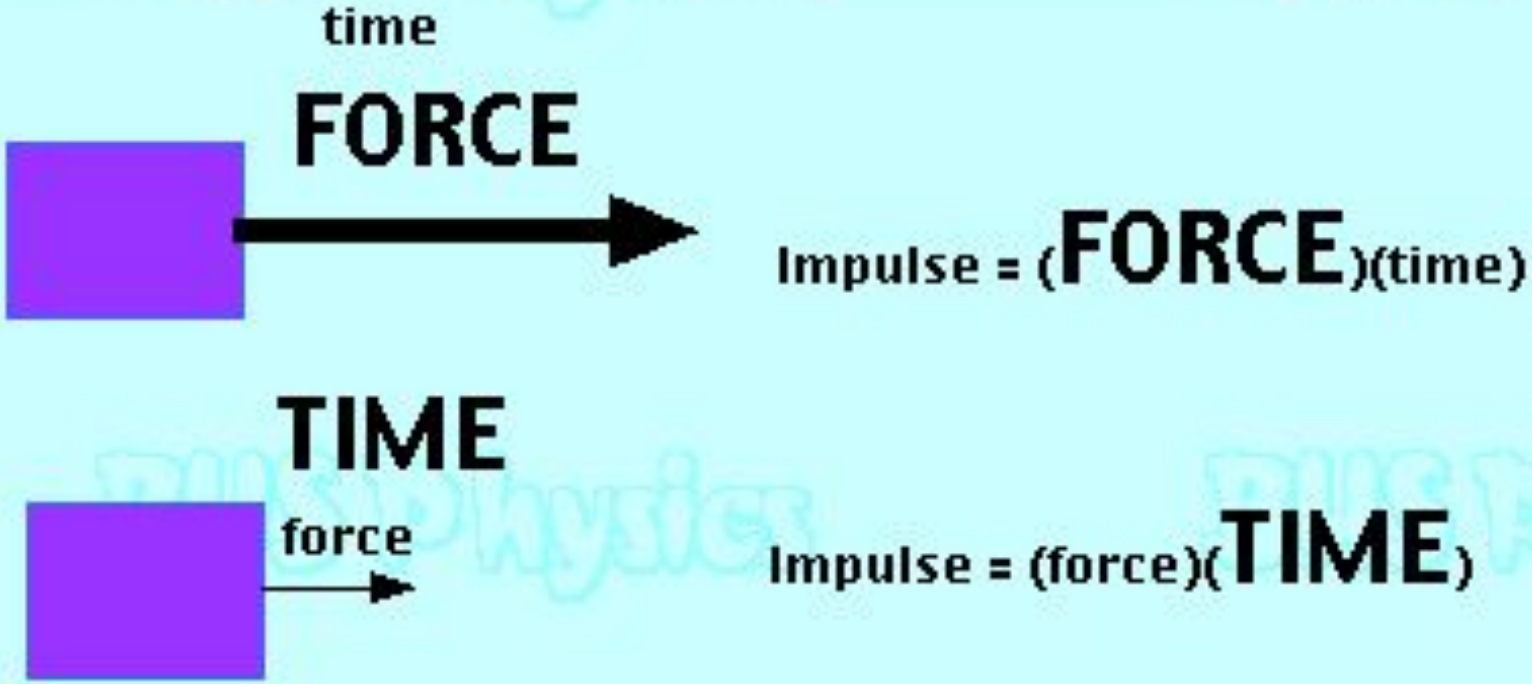
Why?



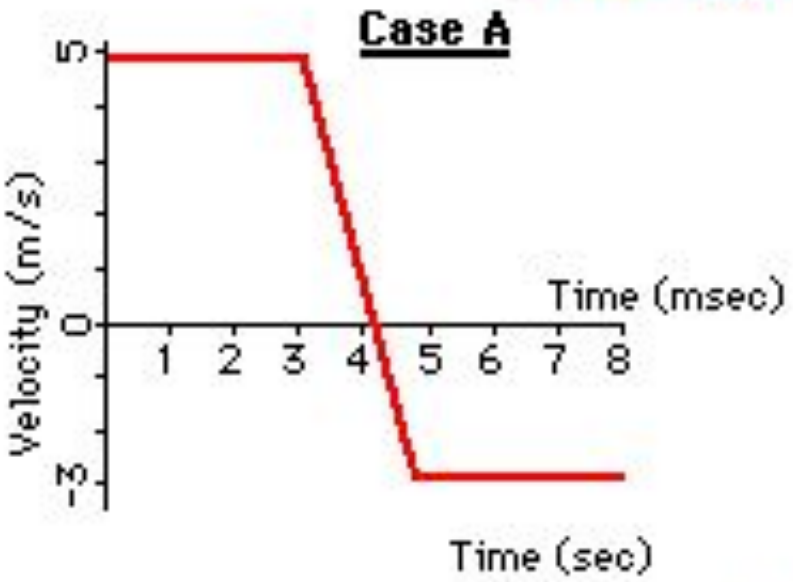
You can get the same impulse by applying a large force for a short time, or applying a small force for a long time.

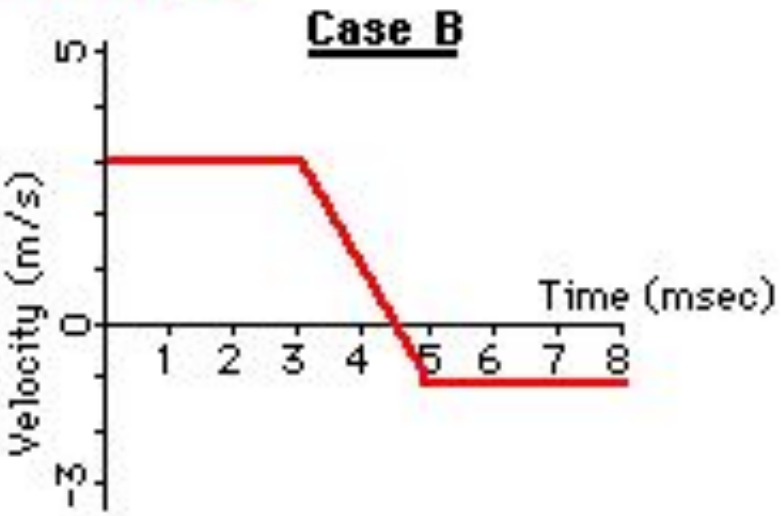
Egg Drop Interactive

- http://www.physicsclassroom.com/Physics-Interactives/Momentum-and-Collisions/Egg-Drop/Egg-Drop-Interactive

Question

Velocity-Time Graph





Greatest velocity change?

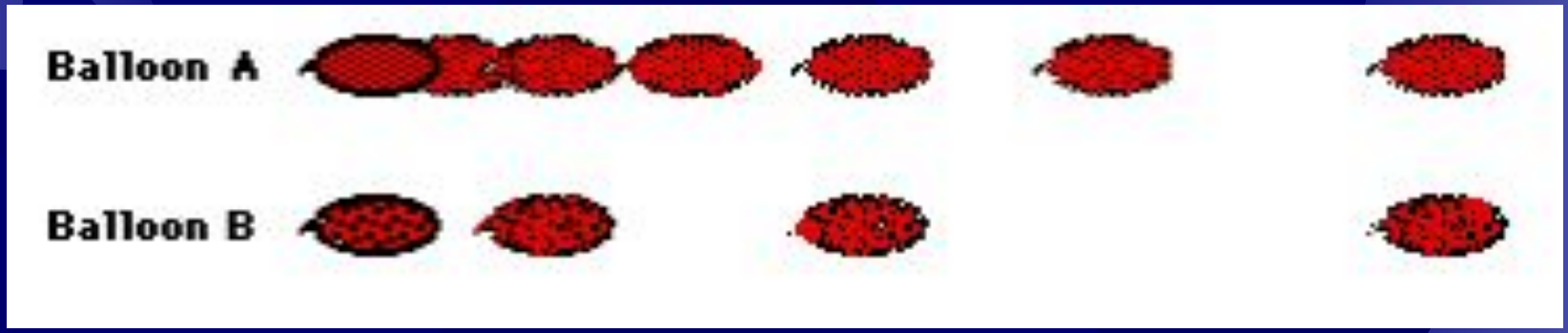
Greatest acceleration?

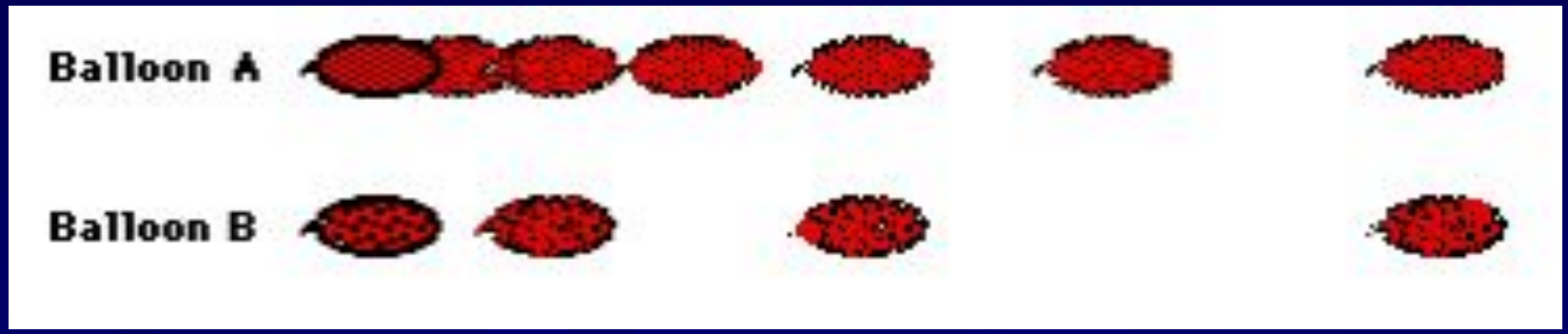
Greatest momentum change?

Greatest Impulse?

Question

- In a Physics demonstration, two identical balloons (A and B) are propelled across the room on horizontal guide wires. The motion diagrams are shown below.





- A) Which balloon has the greatest acceleration?
  B) Which balloon has the greatest final velocity?
- C) Which balloon has the greatest momentum change?
- D) Which balloon experiences the greatest impulse?

Analogy

- A mood is something you have - you are happy, sad, etc. - it is a characteristic of your current state of being. Momentum is something that an object has.
- A "pop quiz" in physics is something that happens to you. An impulse is something that happens to an object.
- Just like a pop quiz in physics can affect your mood, an impulse will affect the momentum of an object.

Conservation of Momentum

- Since ***impulse = change in momentum***, If ***no impulse*** is exerted on an object, the ***momentum of the object will not change***.

Conservation of Momentum

- If ***no external forces*** act on a ***system***, the ***total momentum*** of the system will ***not change***.
- Such a system is called an "***isolated system***".

Conservation of Momentum

- Momentum is ***conserved*** in ***every isolated*** system.

Conservation of Momentum

- Another way to think about it is:

Internal forces can ***never*** change the ***total momentum*** of a system.

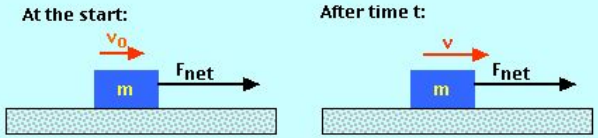
Conservation of Momentum

- In practice, for any event in an **isolated system**:

- $\text{Momentum}_{\text{after}} = \text{Momentum}_{\text{before}}$

Deriving Impulse-Momentum Theorem

Suppose you apply a constant net force, F_{net}, to an object of mass m. Newton's Second Law tells you that the object will accelerate, so if it starts with velocity v_o, after some time t its velocity will be v. This situation is diagrammed below.



From kinematics we know that the acceleration of the object is the rate its velocity changes. In symbols:

$$a = \frac{\Delta v}{t}$$

We also know, from Newton's Second Law, that:

$$a = \frac{F_{net}}{m}$$

Setting the right sides of these equations equal to each other gives:

$$\frac{F_{net}}{m} = \frac{\Delta v}{t}$$

"Cross-multiplying:"

$$F_{net}t = m\Delta v = mv - mv_o = \Delta p$$

This is the Impulse-Momentum Equation.

- Drop objects on foam impulse
- Bend your knees jumping off a table
- Hammer on nail (more F, less t)
- Throwing foam ball full stretch, against wall, hand in way (lessoning impulse)
- Throwing egg at sheet (more t, less F)
- Blow dart cutting off sections (impulse)

The End.