Impulse-Momentum Lecture Notes

Recall – Inertia

Inertia – An measure of a bodies resistance to a change in motion.

Definition of Momentum

Momentum

- Inertia in Motion
- Product of an object's mass and velocity.
- Equation: $p = mv$
- Momentum is a vector quantity.
- Units – kg m/s

Momentum Examples

Calculate the momentum of a 1200 kg truck traveling at 35 m/s east.

How fast must an ordinary housefly traveling to have a momentum equa to that of the truck? The average housefly has a mass of 1 gram.

Revisit Newton's Second Law of Motion

$$F_{net} = ma$$

$$a = \Delta v/\Delta t$$

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

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

$$F_{net}\Delta t = m(v_{final} - v_{initial})$$

$$F_{net}\Delta t = mv_{final} - mv_{initial}$$

$$F_{net}\Delta t = p_{final} - p_{initial}$$

$$\boxed{F_{net}\Delta t = \Delta p}$$

Definition Impulse-Momentum Theorem

$$F_{net}\Delta t = \Delta p$$

Impulse = Change in Momentum

Impulse = $F_{net}\Delta t$

Impulse = The product of the net force and time over which it acts on an object.

Units – Ns

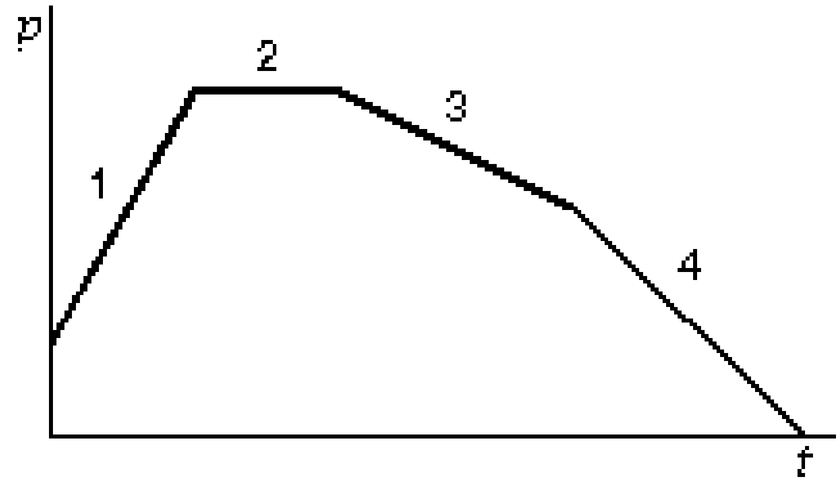
Change in Momentum = Δp

Change in Momentum = The product of an object's mass and its change in velocity.

Units – kg m/s

Impulse-Momentum Example

A particle moves along the *x*-axis. Its momentum is graphed to the right as a function of time.



Rank the numbered regions according to the magnitude of the net force acting on the particle, least to greatest.

$F_{net}\Delta t = \Delta p$

$F_{net} = \Delta p/\Delta t$

F_{net} = slope

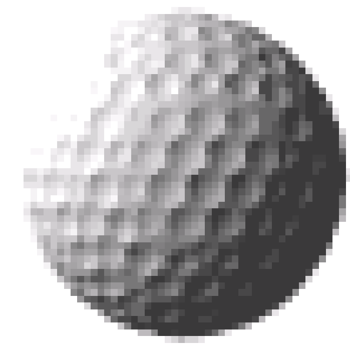
Magnitude = Steepness

Impulse-Momentum Example

What impulse will give a 0.15-kg baseball a momentum change of + 50 kgm/s?

Impulse-Momentum Example

A 0.05 kg golf ball is dropped from the
of a building. It strikes the sidewalk
below at 30 m/s and
rebounds up at 20 m/s.



What’s the magnitude of the impulse due to the collision with the sidewalk?

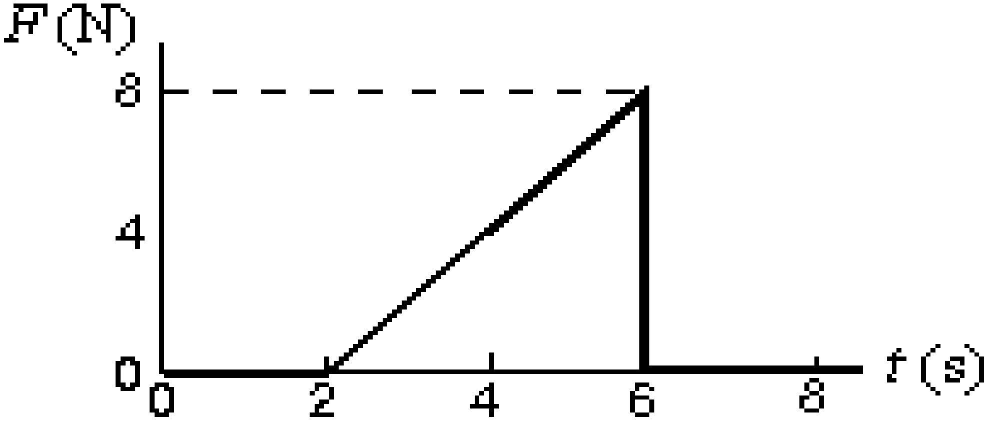
What’s the change in momentum of the ball as a result of the collision with the sidewalk?

What’s the average net force exerted on the golf ball if the collision took 0.025 seconds?

Impulse-Momentum Example

A 2-kg object is acted upon by a single force in the *x* direction in a manner described by the graph shown.

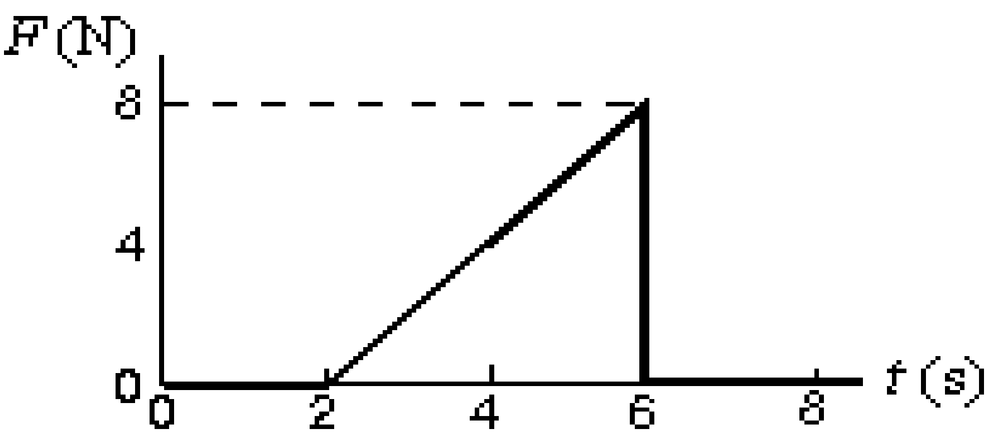
What's the change in the object's momentum?



Impulse-Momentum Example

What's the object's final velocity if it started from rest?

Calculate the average force applied to the object.



Revisit Newton's Third Law of Motion

$$F_{net} = -F'_{net}$$

$$F_{net}\Delta t = -F'_{net}\Delta t$$

$$F_{net}\Delta t = \Delta p$$

$$\Delta p = -\Delta p'$$

Revisit Newton's Third Law of Motion

Continuing . . . $\Delta p = -\Delta p'$

$$p_{final} - p_{initial} = -(p'_{final} - p'_{initial})$$

$$p_{final} - p_{initial} = -p'_{final} + p'_{initial}$$

$$p_{final} + p'_{final} - p_{initial} - p'_{initial} = 0$$

$$p_{final} + p'_{final} - (p_{initial} + p'_{initial}) = 0$$

$$p_{finals} - p_{initials} = 0$$

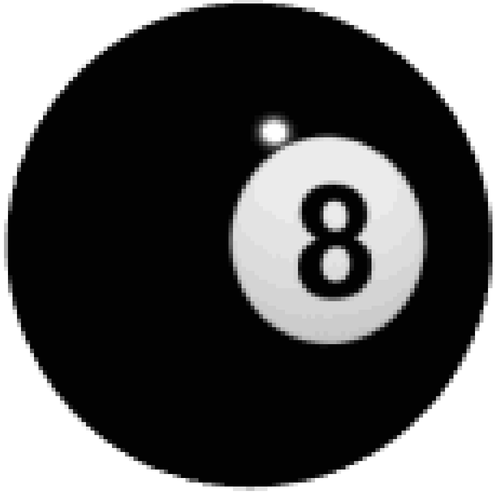
$$\Delta p_{system} = 0$$

Momentum is Conserved

Collision: Elastic

A cue ball, mass 200 grams, moves with a velocity of 20.0 cm/s.

It collides head-on with a stationary 8-ball, mass 200 grams.



After the collision the cue comes to rest.

What's the velocity of the 8-ball?

Prove this is an elastic collision.

Collision: Partially Elastic

A 90 kg fullback running at 8 m/s collides head-on with a 120 kg defensive tackle running at 3 m/s.

The fullback knocks the tackle backwards and continues running at 5 m/s.

What's the velocity of the tackle after the collision?

Collision: Inelastic

A hockey puck, mass 0.10 kg, moving at 32 m/s, strikes an octopus thrown on the ice by a fan at a Detroit Red Wings game.
The octopus has a mass of 0.28 kg. The puck and octopus slide off together. Find their velocity.

Collision Recoil

Two spacemen are floating together with zero speed in a gravity-free region of space.

The mass of spaceman A is 120 kg and that of spaceman B is 80 kg.

Spaceman A pushes B awa from him with B attaining a final speed of 0.5 m/s.

Calculate the final recoil speed of A.

The Boxer

Consider the action of a boxer being hit, as shown to the right, to answer the following questions.

Using < = >

Describe the relationship between the change in momentums during the collision

Δp_{boxer}	?	Δp_{fist}

Describe the relationship between the impulses during the collision

I_{boxer}	?	I_{fist}