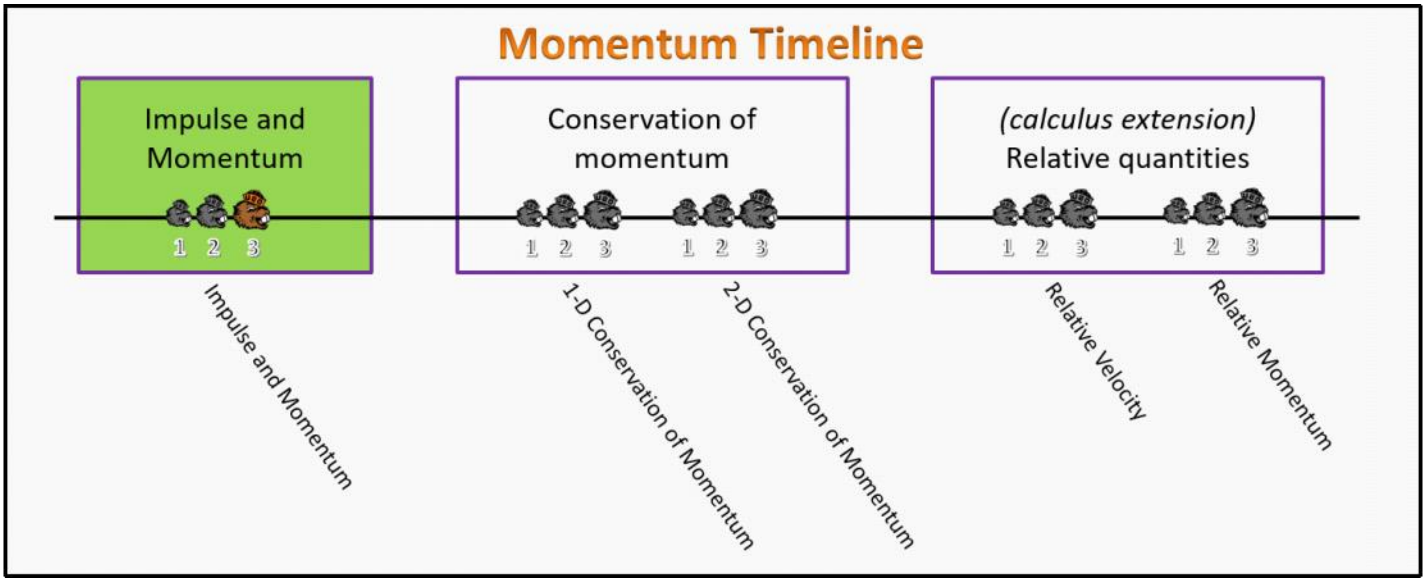
(IM.L1.3-sols) Practice Stage Solutions

Thursday, March 29, 2018 8:34 PM

Impulse and Momentum

Foundation Stage (IM.L1.3)

Post-Lecture 1
Impulse and Momentum



Questions

IM.L1.3-01

Description: identifying constant momentum means zero impulse

Learning Objectives: [x]

Problem Statement: If both mass and velocity of an object are constant, what can you tell about its impulse?

(1) Its impulse would be constant and nonzero.
(2) Its impulse would be zero. *(circled)*
(3) Its impulse would be increasing.
(4) Its impulse would be decreasing.

$\vec{J} = m\Delta\vec{v}$, where $\Delta\vec{v} = \vec{0}$

so $\vec{J} = \vec{0}$

IM.L1.3-02

Description: Why crumpling/collapsing car parts are safer

Learning Objectives: [x]

Problem Statement: Cars these days have parts that can crumple or collapse in the event of an accident. What is the advantage of this?

(1) It reduces injury to the passengers by increasing the time of impact.
(2) It reduces injury to the passengers by decreasing the time of impact.
(3) It reduces injury to the passengers by increasing the change in momentum.
(4) It reduces injury to the passengers by decreasing the change in momentum.

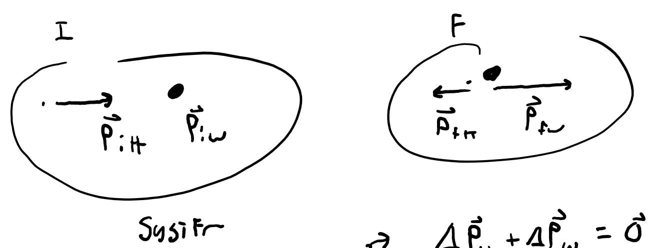
IM.L1.3-03

Description: Collisions, momentum changes, and impulse

Learning Objectives: [x]

Problem Statement: A light hydrogen molecule collides with a heavy water molecule, bouncing off each other. Which of the following statements are true regarding this situation.

(1) The momentum change for the hydrogen molecule is smaller than the water molecule.
(2) The momentum change for the hydrogen molecule is larger than the water molecule.
(3) The momentum lost by one molecule is the same as the momentum gained by the other.
(4) The impulse applied to the hydrogen molecule is greater than the impulse applied to the water.
(5) The impulse applied to the hydrogen molecule is less than the impulse applied to the water.
(6) The impulse applied to the hydrogen molecule is equal in magnitude to the impulse applied to the water.



$$\sum \vec F_{ext} \Delta t = \Delta \vec p$$

$$\Delta \vec p_H + \Delta \vec p_w = \vec 0$$

$$\vec J = \Delta \vec p$$

IM.L1.3-04

Description: Direction of vector quantities

Learning Objectives: [x]

Problem Statement: Which of the following quantities point in the same direction as the change in momentum of an object?

(1) Net force
(2) Acceleration
(3) Impulse
(4) Momentum
(5) Change in position
(6) Change in velocity
(7) Mass
(8) Time interval

$$\sum \vec F \propto \vec a \propto \Delta \vec v \propto \Delta \vec p \propto \vec J$$

IM.L1.3-05

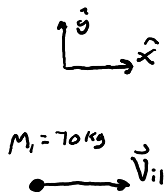
Description: 1D momentum and impulse calculation of soccer player and ball

Learning Objectives: [x]

Problem Statement: A 70kg soccer player, running at 10m/s kicks a 0.4kg ball, which travels at 50m/s.

(a) What is the magnitude of the momentum of the player?

(1) 80 kg m/s
(2) 60 kg m/s
(3) 7 kg m/s
(4) 700 kg m/s



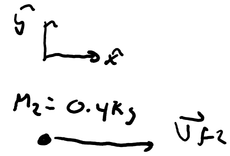
$\vec{P}_{1i} = 70kg\langle 10,0\rangle$

$\vec{P}_{1i} = \langle 700 \frac{kg\,m}{s}, 0\rangle$

$|\vec{P}_{1i}| = 700 \frac{kg\,m}{s}$

(b) What is the magnitude of the momentum of the ball?

(1) 50.4 kg m/s
(2) 49.6 kg m/s
(3) 0.008 kg m/s
(4) 20 kg m/s



$\vec{P}_{2f} = 0.4kg\langle 50,0\rangle m/s$

$\vec{P}_{2f} = \langle 20,0\rangle \frac{kg\,m}{s}$

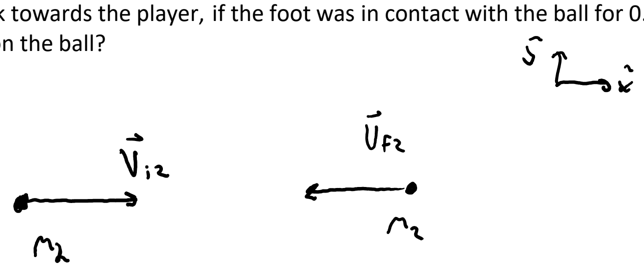
$|\vec{P}_{2f}| = 20 \frac{kg\,m}{s}$

(c) The ball is then kicked back towards the player, in the opposite direction with the same speed. Has the momentum of the ball changed?

(1) No, same mass and speed means same momentum
(2) No, same mass and opposite velocity means same momentum
(3) Yes, same mass but different velocity means different momentum
(4) Impossible to determine without knowing the force acting on the ball during the kick

(d) When the ball was kicked back towards the player, if the foot was in contact with the ball for 0.22 seconds, what is the magnitude of the impulse acting on the ball?

(1) 20 kg m/s
(2) 40 kg m/s
(3) -20 kg m/s
(4) -40 kg m/s



$\Delta\vec{P} = \vec{P}_{2f} - \vec{P}_{2i}$

$= \langle -20,0\rangle \frac{kg\,m}{s} - \langle 20,0\rangle \frac{kg\,m}{s}$

$$= \langle -20, 0 \rangle \frac{kg\,m}{s} - \langle 20, 0 \rangle \frac{kg\,m}{s}$$

$$\Delta \vec{p} = \langle -40, 0 \rangle \frac{kg\,m}{s}$$

$$\vec{J} = \Delta \vec{p}$$

$$|\vec{J}| = 40 \frac{kg\,m}{s}$$

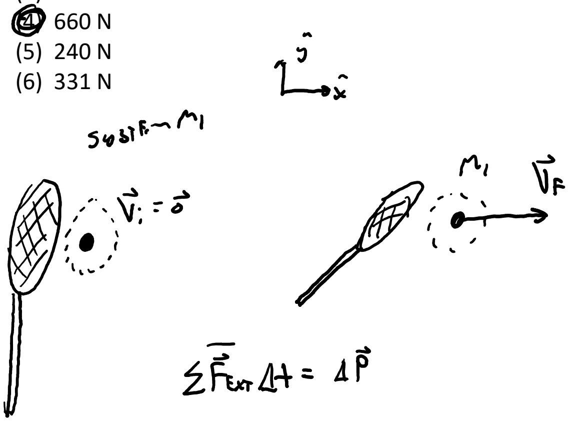
IM.L1.3-06

Description: Using impulse to calculate force of tennis racket on a ball during a match

Learning Objectives: [x]

Problem Statement: During the 2007 French Open, Venus Williams hit the fastest recorded serve in a premier women's match, reaching a speed of 58 m/s (209 km/h). What was the average force exerted on the 0.057kg tennis ball by Venus Williams's racket? Assume that the ball's speed just after impact was 58 m/s, the horizontal velocity before impact is negligible, and t hat the ball remained in contact with the racket for 5.0 ms (milliseconds).

(1) 0.02 N
(2) 3.31 N
(3) 113 N
(4) 660 N
(5) 240 N
(6) 331 N



$$\Sigma \vec{F}_{Ext} \Delta t = \Delta \vec{p}$$

$$\Sigma \vec{F}_{Ext,x} \Delta t = \Delta p_x$$

$$\Sigma \vec{F}_{Ext,x} (5 \times 10^{-3} s) = \underbrace{0.057kg(58\ m/s)}_{p_{fx}} - \underbrace{0.057kg(0\ m/s)}_{p_{ix}}$$

$$\Sigma \vec{F}_{Ext,x} \approx 661.2\ N$$

IM.L1.3-07

Description: Basic calculation of impulse

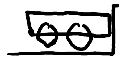
Learning Objectives: [x]

Problem Statement: Suppose a child drives a bumper car head on into the side rail, which exerts a force of 4000 N on the car for 0.200 s.

0.200 s.

(a) What magnitude impulse, in kg·m/s, is imparted by this force?

System Car



$$J_x = \sum F_{ext,x} \Delta t$$

$$= -(4000\ N)(0.20\ s)$$

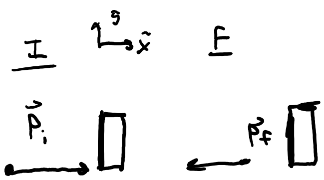
$$J_x = -800\ Ns$$

$$|\vec{J}| = \sqrt{J_x^2 + J_y^2}, \quad J_y = 0$$

$$|\vec{J}| = 800\ Ns$$

(b) Find the final velocity of the bumper car if its initial velocity was 2.80 m/s and the car plus driver have a mass of 200 kg. You may neglect friction between the car and floor.

(1) 1.20 m/s towards the wall
(2) 1.20 m/s away from the wall ✓
(3) 0 m/s, it stops the car
(4) 0.20 m/s towards the wall
(5) 0.20 m/s away from the wall



$$J_x = \Delta P_x$$

$$-800\ NS = \underbrace{200\,kg\ V_{fx}}_{P_{fx}} - \underbrace{200\,kg\,(2.80\ m/s)}_{P_{ix}}$$

$$V_{fx} = -1.2\ m/s$$

IM.L1.3-08

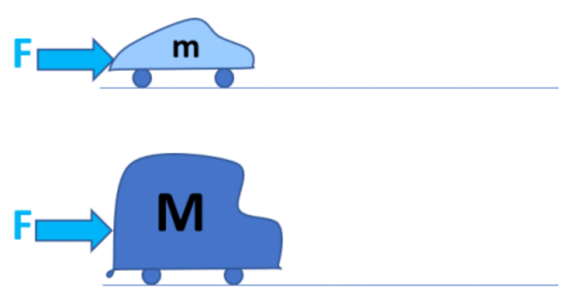
Description: Identify final velocities of objects with different masses, with the same force applied for the same time interval.

Learning Objectives: [6,?]

Problem Statement: A force F pushes a car with a small mass m, and another identical force F pushes a truck with a bigger mass M. The car and truck are both pushed for the same amount of time. Which is going faster at the end of the time?

(1) The car ✓

(2) The truck



$$\sum F_x \Delta t = \Delta P_x$$

$$\sum F = const$$

$$\Delta t = const$$

So

$$Const = M \Delta v$$

Both have $v_{ix} = 0$

$Const = m \Delta v$ — Both have $v_{ix} = 0$

$Const = m \vec{v}_f - m \vec{v}_{ix}$ (second term crossed out)

so $v_{fx} \propto \frac{1}{m}$

w/ $m_T > m_C$

$v_{fT} < v_{fC}$

IM.L1.3-09

Description: 2-D change in velocity, impulse, force, and acceleration

Learning Objectives: [x]

Problem Statement: You're maneuvering your 1000 kg Scooty Puff Pro spaceship to connect with another ship. Initially the ship moves in the positive x-direction with a speed of 50 m/s. After three minutes and 20 seconds, it's traveling in the positive y-direction with a speed of 30 m/s.

(a) What is the change in velocity of the ship?

(1) < 50 , 30 > m/s
(2) < -50 , -30 > m/s
(3) < -50 , 30 > m/s (circled)
(4) < 50 , -30 > m/s

$\Delta \vec{v} = \vec{v}_f - \vec{v}_i$

$= \langle 0, 30 \rangle - \langle 50, 0 \rangle$

$\Delta \vec{v} = \langle -50, 30 \rangle$ m/s

(b) What is the impulse acting on the ship?

(1) < 50,000 , 30,000 > kg·m/s
(2) < -50,000 , -30,000 > kg·m/s
(3) < -50,000 , 30,000 > kg·m/s (circled)
(4) < 50,000 , -30,000 > kg·m/s

$\vec{J} = \Delta \vec{p}$

$= m \Delta \vec{v}$

$= 1000 \text{ kg} \langle -50, 30 \rangle$ m/s

$\vec{J} = \langle -50000, 30000 \rangle$ Ns

(c) What is the average net force acting on the ship?

(1) < -250 , 150 > N (circled)
(2) < -350 , 200 > N
(3) < 100 , 66.7 > N
(4) < 50 , -150 > N
(5) < -500 , 300 > N

3 min → 180 s
20 sec → 20 s
$\Delta t = 200$ s

$\overline{\sum \vec{F}_{ext}} \Delta t = \Delta \vec{p}$

$\sum \vec{F}_{ext} = \frac{\Delta \vec{p}}{\Delta t}$

$= \frac{\langle -50000, 30000 \rangle \text{ Ns}}{200 \text{ s}}$

(d) What is the average acceleration of the ship?

(1) < 5 , 3 > m/s^2
(2) < -5 , 3 > m/s^2
(3) < -1.5 , 0.75 > m/s^2
(4) < 0.35 , 0.25 > m/s^2
(5) < -0.25 , 0.15 > m/s^2

$\sum \vec{F}_{ext} = m \vec{a}$

$\vec{a} = \frac{\langle -250, 150 \rangle \text{ N}}{1000 \text{ kg}}$

$\vec{a} = \langle -0.25, 0.15 \rangle \text{ m/s}^2$

$200\,s$

$\sum \vec{F}_{ext} = \langle -250, 130 \rangle N$

IM.L1.3-10

Description: force vs time and impulse

Learning Objectives: [x]

Problem Statement: Wiley Coyote bought some new rockets skates to help him catch The Roadrunner. The rockets applies a force as a function of time shown below. As The Roadrunner runs by, the 11 kg Wiley, who is skating in the same direction, fires hi s rockets. After the 10 s period, he is traveling at 12 m/s. What was Wiley's speed right before he fired the rockets?

(1) 2 m/s
(2) 3 m/s
(3) 5 m/s
(4) 6 m/s
(5) 8 m/s

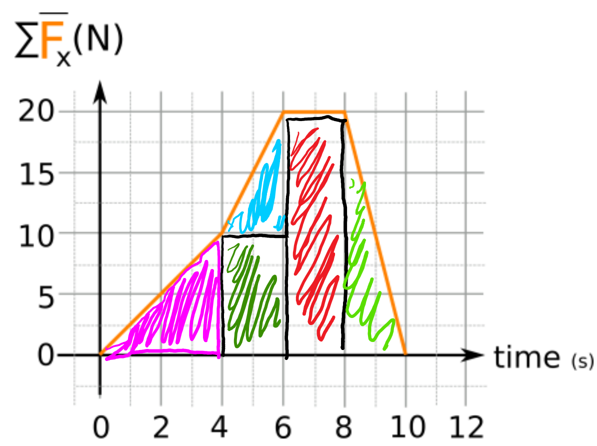
$\sum F_x \Delta t = \Delta P_x$

AREA

$110\ Ns = m v_{fx} - m v_{ix}$

$110 = 11(12) - 11(v_{ix})$

$v_{ix} = 2\ m/s$



AREA

$\frac{1}{2}(4)(10) + 2(10) + \frac{1}{2}(2)(10) + 2(20) + \frac{1}{2}(2)(20)$

$20\ Ns + 20\ Ns + 10\ Ns + 40\ Ns + 20\ Ns$

$110\ Ns$