PHY131 F   Fall 2020
Class 18

Today:

- 6.5 Solving Problems with Momentum
- Team-Up Quiz on Chapter 6!
- 6.6 Jet Propulsion
- 6.7 Collisions in 2D

This video was taken yesterday by NASA's Osiris-Rex automated probe, which is currently 320 million km away from Earth, investigating 'earth-crossing asteroids'.
Its mission is to use a nitrogen blast to blow away rocks and dust from the surface of the asteroid Bennu, and return with a sample to Earth for further analysis. It should return home by 2023.

1

Poll

Crazy Friday: Let's Choose a Zoom-Filter my face today

What Studio Filter would you prefer on my face today?

A. Happy Sprout

B. "Aye Aye Captain"

C. Prancer

D. Magicorn

E. 14 Karat Gold

2

Example: Problem 6.71

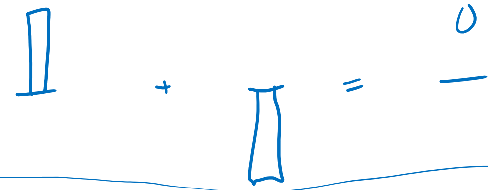
A record rainstorm produced 304.8 mm (approximately 1 ft) of rain in 42 min. Estimate the average force that the rain exerted on the roof of a house that measures 10 m× 16 m. Assume the (terminal) speed of the rain to be 10 m/s.

SKETCH & TRANSLATE.

→ Rain must stop when it hits the roof. This requires an upward force from the roof on rain. By Newton's 3rd law, the rain exerts an equal mag. force on the roof. Define system = rain. Define +x = down.

SIMPLIFY & DIAGRAM

P. Initial + Impulse = P final.



What is mass of rain?

Assume mass density $\rho = 1000\ \frac{kg}{m^3}$

depth = 0.3048 m

$m_r = V_r \cdot \rho = d \times w \times l \times \rho$

$= 0.3048 \times 10 \times 16 \times 1000$

$m_r = 48768$ kg !! A lot! ~49 tons.

3

Example: Problem 6.71

A record rainstorm produced 304.8 mm (approximately 1 ft) of rain in 42 min. Estimate the average force that the rain exerted on the roof of a house that measures 10 m× 16 m. Assume the (terminal) speed of the rain to be 10 m/s.

REPRESENT MATHEMATICALLY

$m_r v_{irx} + J_x = m_r v_{frx}$ (= 0)

$m_r v_{irx} + F_x \Delta t = 0$

Solve for F:

$F = -\frac{m_r v_{rix}}{\Delta t}$

SOLVE & EVALUATE

SI Units to get F in N.

$\Delta t = 42\ \text{min} \left(\frac{60\ s}{1\ \text{min}}\right)$

$\Delta t = 2520\ s$

$F = -\frac{48768 \cdot (10)}{2520}$

$F_{\text{Roof on rain}} = -193.5$ ← 193.5 N, up!

$F_{\text{rain on roof}} = 190$ N, down.

4

Elastic vs Inelastic collisions - Poll

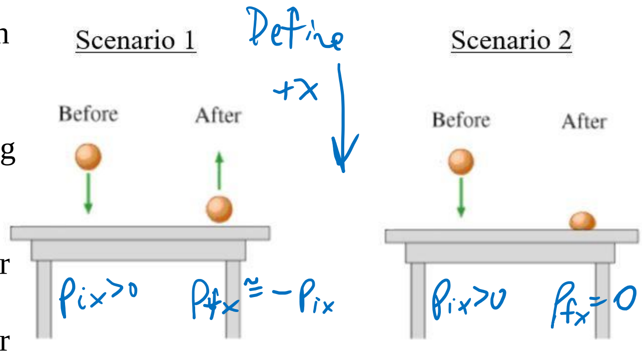
Two objects of the same mass strike a flat tabletop at the same speed, as shown. However, in Scenario 2 the object stops when it hits the table, and in Scenario 1, the object bounces off the table with an equal speed in the opposite direction. Which of the following statements is true about the change in momentum of the two objects?

A. The object's change in momentum is larger in Scenario 1. ~2x as much,

B. The object's change in momentum is larger in Scenario 2.

C. The object's change in momentum is the same in both scenarios.

D. It depends on the time interval for which each object is in contact with the table.



$\Delta p_x = p_{fx} - p_{ix}$
$= -p_{ix} - p_{ix}$
$= -2p_{ix}$

$\Delta p_x = -p_{ix}$

5

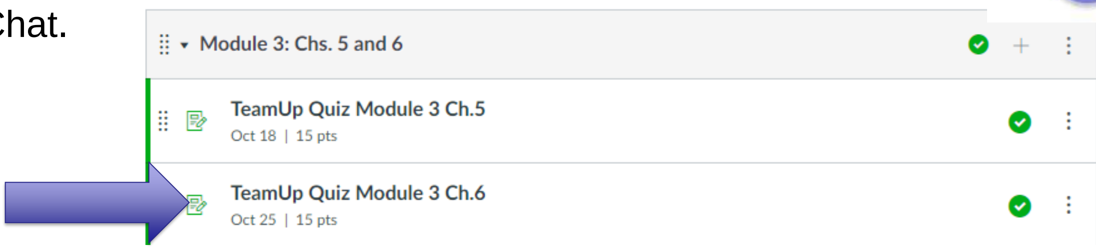
Elastic vs Inelastic collisions

We will learn more about Elastic vs Inelastic collisions in Chapter 7.
The difference turns out to be how much **energy** of motion is converted **to internal energy** during a collision.
Note: When a room sized object, like a ball, collides with the floor or wall or something connected to the Earth, the Earth must be considered as part of the system in which momentum is constant.

6

TeamUp Time!!

- Today you will be doing three multiple choice questions, all from Chapter 6, as a team of 2-4 students in your Practicals Pod.
- Your pod-team shares the mark!
- I'm going to mute here for 10 minutes; right now you should open Microsoft Teams and someone (most recent Facilitator) should place a **video call** to all 3 or 4 members of your Pod-Chat.



7

Now: TeamUp! You have 10 minutes

- The first step is to decide who will be the TeamUp **Driver**
- All students must log-in to Quercus [You will now have three windows open: my zoom lecture, Microsoft Teams, and Quercus]
- **Non-drivers**: Wait!
- **Driver**: Go to the TeamUp Quiz Ch.6 in this module, click Go to Tool, then Create a Group. Let everyone in the Breakout Room know the session ID. Then WAIT – don't drive off alone!
- **Non-drivers**: Once you get the session ID, go to the TeamUp Quiz in this module, click Go to Tool, then Join Session and type the ID you were given.
- Once everyone in your room arrives in TeamUp, start going through the questions. Please **achieve consensus** before the driver submits.
- YOU MAY BEGIN! Note: if your pod-mates are available on Microsoft Teams right now, go to the PHY131 Help Centre and I'll set up breakout rooms there. Zoom Meeting ID: 938 0964 2256, Passcode: 723874

8

Question 1 Discussion

A very bouncy rubber ball is dropped from a certain height and hits the floor with a downward speed *v*.

Since it is so elastic, the ball bounces back with the same speed *v* going upward.

Which of the following statements about the bounce are correct?

A. The ball had the same (mag.) momentum just before and just after the bounce. ← momentum is a vector

B. The magnitude of the ball's momentum was the same just before and just after the bounce.

C. The ball's momentum was constant during the bounce.

D. None of the above statements is correct.

Question 2 Discussion

During a head-on collision, how does an air bag protect a passenger in the car?

A. It decreases the impulse exerted the passenger.

B. It decreases the initial momentum of the passenger.

C. It lengthens the stopping time interval for the passenger, and decreases the force exerted on them during the collision.

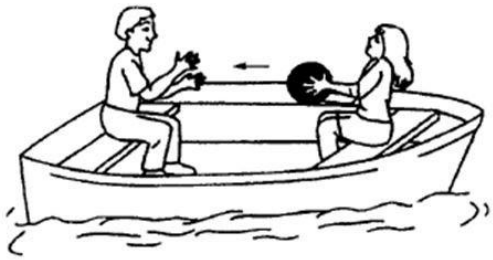
D. It shortens the stopping time interval for the passenger, and increases the force exerted on them during the collision.

Impulse is set by properties of crash

$\vec{J} = \vec{F} \Delta t$

if $\Delta t \uparrow$, $|\vec{F}| \downarrow$ for same $|\vec{J}|$

Question 3 Discussion



As shown, two people sit at opposite ends of a boat, that is initially at rest.

The person to the right throws a large ball to the person on the left. What is the direction of the velocity of the people-boat system at the moment immediately after the ball is thrown and, later, after the ball is caught by the person on the left?

(Assume that air and water friction are negligible.)

A. Immediately after the Ball is Thrown: Right, After the Ball is Caught: At rest.

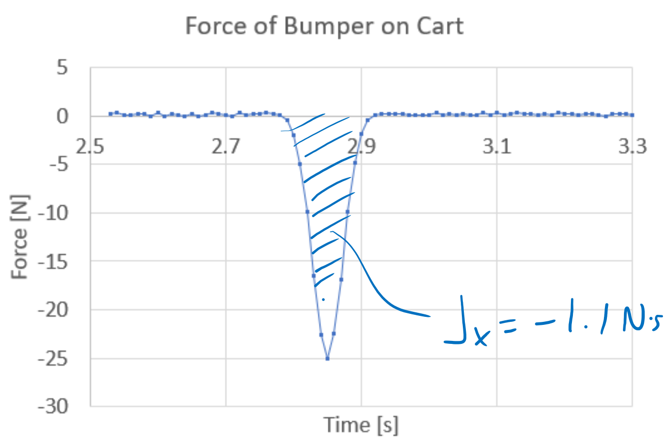
B. Immediately after the Ball is Thrown: Left, After the Ball is Caught: At rest.

C. Immediately after the Ball is Thrown: At rest, After the Ball is Caught: At rest.

D. Immediately after the Ball is Thrown: Right, After the Ball is Caught: Left.

Collision Cart Demonstration

- A 0.5 kg cart on a low-friction track travels in the +x direction at +1.2 m/s.
- It collides with the bumper at the end. On the bumper is a Force sensor which measures the x-component of the force on the cart as a function of time.
- The plot the force sensor makes is displayed on the computer.
- The area of the spike is -1.1 N s.
- What do you expect will be the final velocity of the cart?



Collision Cart Analysis

- A 0.5 kg cart on a low-friction track travels in the +x direction at +1.2 m/s.
- The impulse of the bumper on the cart is -1.1 N s.
- What do you expect will be the final velocity of the cart?

SKETCH & TRANSLATE.

initial: $m_c = 0.5$ kg, $v_{ix} = +1.2$ m/s

Define system = cart.

Final: $v_{fx} = ?$

$J_x = -1.1$ N·s

SIMPLIFY & DIAGRAM

$p_{ix} + J_x = p_{fx}$

REPRESENT MATHEMATICALLY

$m_c v_{ix} + J_x = m_c v_{fx}$

Solve for $v_{fx} = v_{ix} + \frac{J_x}{m_c}$

SOLVE & EVALUATE

$v_{fx} = +1.2 - \frac{1.1}{0.5}$

$v_{fx} = -1.0$ m/s

cart bounces, loses some kinetic energy

Collision Cart Analysis – Stupid Question

- A 0.5 kg cart on a low-friction track travels in the +x direction at +1.2 m/s.
- The impulse of the cart on the bumper is +1.1 N s.
- What do you expect will be the final velocity of the bumper?

SKETCH & TRANSLATE.

initial: bumper is at rest.

$J_x = +1.1$ N.

What is mass of bumper?

Define "system" → bumper is connected to the track, which is connected to the Earth.

System = bumper + earth, $m_{sys} = 6 \times 10^{24}$ kg

SIMPLIFY & DIAGRAM

$p_{ix} + J_x = p_{fx}$

REPRESENT MATHEMATICALLY

$0 + J_x = m_{sys} v_{fsys}$

$v_{f\,bumper} = \frac{J_x}{m_{sys}}$

SOLVE & EVALUATE

$= \frac{1.1}{6 \times 10^{24}} = 1.8 \times 10^{-25}$ m/s

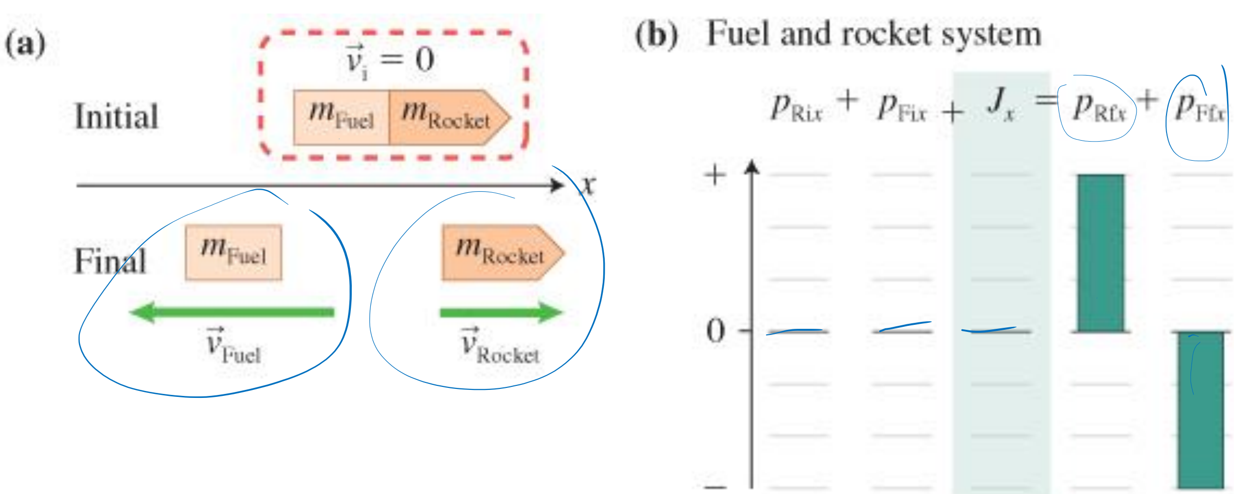
$\approx$ zero.

6.6 Jet Propulsion

- Cars change velocity because of an interaction with the road; a ship's propellers push water backward.
- A rocket in empty space has nothing to push against.
  - If the rocket and fuel are at rest before the rocket fires its engines, the momentum is zero. Because there are no external impulses, after the rocket fires its engines, the momentum should still be zero.
  - Burning fuel is ejected backward at high velocity, so the rocket must have nonzero forward velocity.

15

6.6 Jet Propulsion



16

6.6 Jet Propulsion

Thrust

- Thrust is the force exerted by the fuel on a rocket during jet propulsion.
- Typical rocket thrusts measure approximately 10^6 N, and exhaust speeds are more than 10 times the speed of sound.
- Thrust provides the impulse necessary to change a rocket's momentum.
  - The same principle is at work when you blow up a balloon, but then open the valve and release it, and when you stand on a skateboard with a heavy ball and throw the ball away from you.

17

Before Class 19 on Monday

- Please read the first two sections of Chapter 7:
- 7.1 Work and Energy
- 7.2 Conservation of Energy

Not on Midterm 3

- Remember on Tuesday at 8:10pm there will be a Midterm Assessment on Chapters 5 and 6. 10 Multiple Choice questions, one at a time, in 30 minutes (same format as Midterm 1).

- As usual, I'll be around until 12:30, then a TA will be in the PHY131 Help Centre:
- Zoom Meeting ID: 938 0964 2256
- Passcode: 723874

18