Conserved vs Constant and Linear Momentum

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All documents for today's meeting are at https://drive.google.com/drive/folders/1dd9zS99n4YALibVvYR12hZp1n3cWOkZp?usp=sharing

Please rename yourself

First name

Where you teach - high school or college

Country

Example: Eugenia, University, USA

Watch two videos and notice the difference in the outcomes.

https://youtu.be/81G2JUiwI0c

https://youtu.be/fyChulcTVGQ

All together, use whiteboard to draw the bar charts

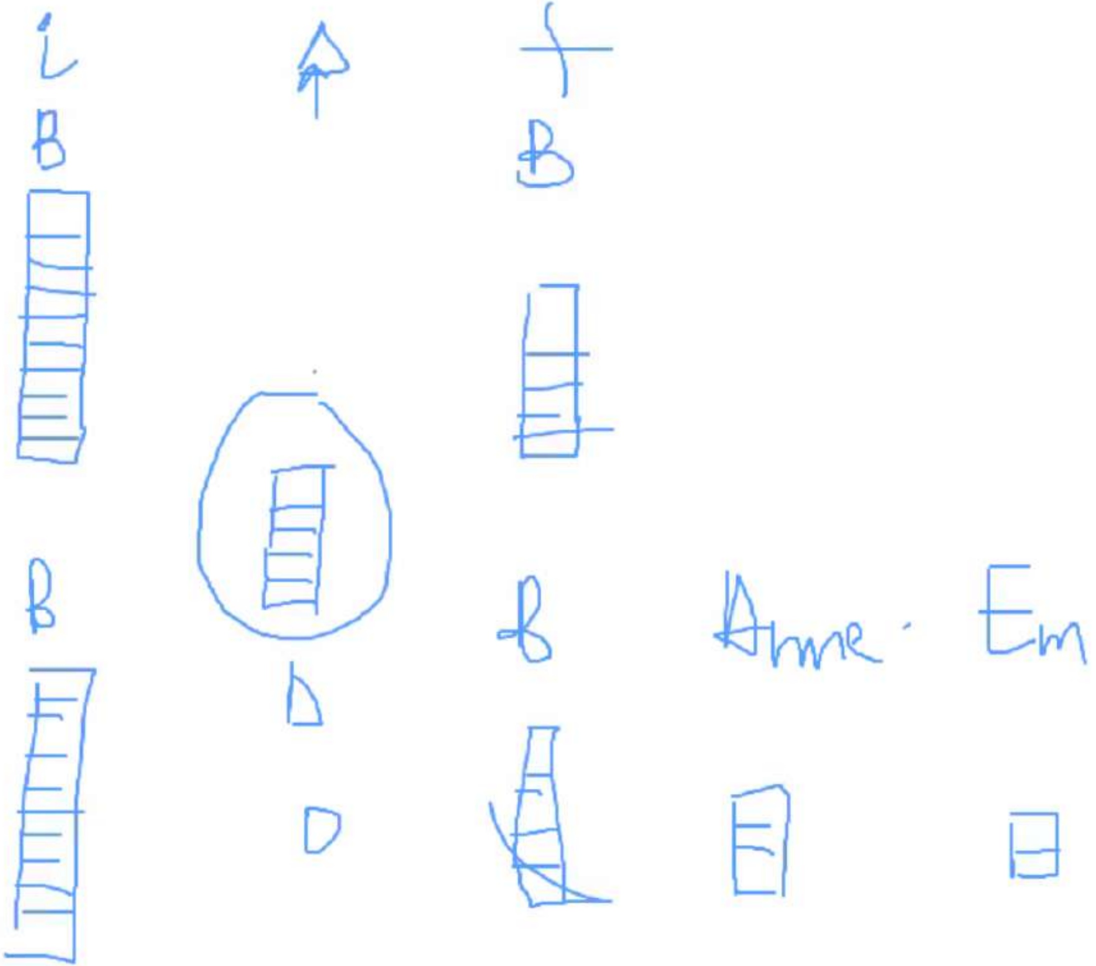
Imagine that you have 10 apples in a bowl. You give 3 to your friend Anne and 2 to your friend Emily. What happened to the number of the apples when considering just the apples in the bowl as the system? Then, repeat the same analysis for the system that contains all apples (no matter where they end up). Can you say that the number of apples in the system is constant in both cases? Can the apples disappear?

Can you represent the process with a bar chart for two systems:

(1)apples in your bowl only and

(2) all apples together.

Choose initial state before you see Anne and Emily and the final after they both got their apples.


i
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Conserved vs constant

A quantity is **constant** if it is the same for different clock readings: constant velocity, constant acceleration, constant number of apples in the second system in our previous activity.

What does it mean when we say “the quantity is **conserved**”? What are examples of conserved quantities?

Does it mean that a conserved quantity is always constant?

So far we focused on the forces that external objects exert on our system of choice, on the acceleration of the system but we never asked ourselves a question about what happens to those other objects that exerts the forces. What if we included them in the system? Let’s figure it out!

Long activity broken down for 4 teams

OALG 6.2.1. Observe and find a pattern

Observe the following four videos of the experiments with a two-object system. Two carts (the system consists of *both* carts) move on a dynamics track:

a. Cart A (500 g), moving right at constant 0.37-m/s speed, hits identical cart B (500 g) that is stationary. Cart A stops and cart B starts moving at the speed of 0.37 m/s to the right. https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-2-1a

b. Cart A loaded with a block (total mass of the cart with the block is 1470 g), and moving right at 0.31 m/s hits stationary cart B (mass 500 g). After the collision, both carts move right: cart B at the speed of 0.47 m/s and cart A at the speed of 0.15 m/s.
https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-2-1b

c. Cart A (500 g), with Velcro attached to its front, moves right at 0.31 m/s. Identical cart B (500 g) moves left at constant speed 0.31 m/s. The carts collide, stick together, and stop https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-2-1c

d. Repeat experiment **c.** but this time cart A is loaded (with a block, total mass is 1470 g) moves right at constant speed of 0.35 m/s. Cart B (500 g) moves left at constant speed of 0.35 m/s. After the collision, both carts stick together and travel right at the speed of 0.17 m/s.
https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-2-1d

For *each* experiment, sketch the process before the collision and after the collision. Create a table like the one that follows to help you determine if anything is the same before and after the collision for the two-cart system. (Use the table below to look for quantities.)

Team 1

OALG 6.2.1. Observe and find a pattern

Observe the following four videos of the experiments with a two-object system. Two carts (the system consists of *both* carts) move on a dynamics track:

a. Cart A (500 g), moving right at constant 0.37-m/s speed, hits identical cart B (500 g) that is stationary. Cart A stops and cart B starts moving at the speed of 0.37 m/s to the right.
https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-2-1a

Analyze the data in the table in Team 1 OALG 6.2.1 a

Make a list of physical quantities that are the same before and after collision.

Mass cart 1

Mass cart 2

Velocity of cart A before and cart B after collision are the same

Mass times speed before and after collision

Mass times x-velocity component before and after

Team 2

b. Cart A loaded with a block (total mass of the cart with the block is 1470 g), and moving right at 0.31 m/s hits stationary cart B (mass 500 g). After the collision, both carts move right: cart B at the speed of 0.47 m/s and cart A at the speed of 0.15 m/s.
https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-2-1b

Analyze the data in the table
https://docs.google.com/document/d/1nkxXjvN_qucVegwRgA8FwI_VXjMCVigyfffEic7ULk0/edit

Make a list of physical quantities that are the same before and after collision.

- Mass A, Mass B, Total mass of A & B, Mass times Speed Combined (3rd row and 6th row)

Team 3

c. Cart A (500 g), with Velcro attached to its front, moves right at 0.31 m/s. Identical cart B (500 g) moves left at constant speed 0.31 m/s. The carts collide, stick together, and stop
https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-2-1c

Analyze the data in the table

https://docs.google.com/document/d/1ISWadGjZ2EV3ZriOgO5pQ9nSzENaVuQmnnvbuNiXfwI/edit

Make a list of physical quantities that are the same before and after collision.

If system = both carts:

Combined Mass, mass x velocity combined

Team 4

d. Repeat experiment **c.** but this time cart A is loaded (with a block, total mass is 1470 g) moves right at constant speed of 0.35 m/s. Cart B (500 g) moves left at constant speed of 0.35 m/s. After the collision, both carts stick together and travel right at the speed of 0.17 m/s. https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-2-1d

Analyze the data in the table

https://docs.google.com/document/d/1POUTVvuXRYyA9RVZkU1hf22kV1GWIAPejG09EbrV7kQ/edit

Make a list of physical quantities that are the same before and after collision.

- Considering combined physical quantities (car A + car B) remain the same the mass, the mass times speed and the mass times x- velocity component

After you come up with a physical quantities that are the same before and after each collision, decide which quantity remains constant in **all four** experiments.

Mass

Sum of mass times component of velocity in the x direction - momentum of a system

Mass times velocity = momentum of one object [*p*]= kg times m/s

Team 1 OALG 6.2.3

6.2.3 Test your idea

a. Observe the following experiment https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-2-3a.

b. Use the data from the experiment and your knowledge of the physical quantity you invented in Activity 6.2.1 to do the following: predict the speed of the carts and the shape of the velocity-*vs*-time graph after they collide and stick together.

c. Watch the video of the carts after the collision https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-2-3b and compare your prediction to the outcome. Do you need to revise your idea or the additional assumptions you made?

Prediction of velocity after: 0.294 m/s

Actual: Approximately the same!

Team 2 OALG 6.2.3

6.2.3 Test your idea

a. Observe the following experiment https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-2-3a.

b. Use the data from the experiment and your knowledge of the physical quantity you invented in Activity 6.2.1 to do the following: predict the speed of the carts and the shape of the velocity-*vs*-time graph after they collide and stick together.

c. Watch the video of the carts after the collision https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-2-3b and compare your prediction to the outcome. Do you need to revise your idea or the additional assumptions you made?

Initial

m1*v1 = (810g)*(0.4 m/s) = 324 g*m/s

m2*v2 = (293 g) * (0 m/s) = 0 g* m/s

Sum = 324 g* m/s

Final Predicted

Sum of m1 and m2 = 1103 g

Combined m*v = 0.293 g*m/s

Team 3 OALG 6.2.3

6.2.3 Test your idea

a. Observe the following experiment https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-2-3a.

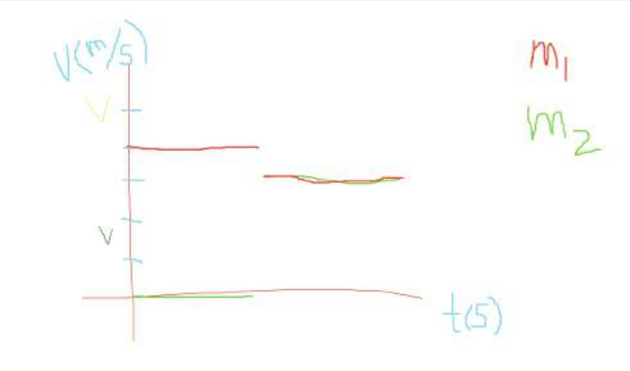
b. Use the data from the experiment and your knowledge of the physical quantity you invented in Activity 6.2.1 to do the following: predict the speed of the carts and the shape of the velocity-*vs*-time graph after they collide and stick together.

Predicted: 0.29m/s Outcome 0.29m/s but it slows down

c. Watch the video of the carts after the collision https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-2-3b and compare your prediction to the outcome. Do you need to revise your idea or the additional assumptions you made?

It slows down due to friction maybe, but not much friction between initial and final because it was almost instantaneous.

Team 4 OALG 6.2.3



6.2.3 Test your idea

a. Observe the following experiment https://mediaplaye sci-OALG-6-2-3a.

b. Use the data from the experiment and your knowledge of the physical quantity you invented in Activity 6.2.1 to do the following: predict the speed of the carts and the shape of the velocity-*vs*-time graph after they collide and stick together.

c. Watch the video of the carts after the collision https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-2-3b and compare your prediction to the outcome. Do you need to revise your idea or the additional assumptions you made?

All together 6.2.4 (save for lab as it requires uncertainties)

OALG 6.2.4 Test your idea (ALG 6.2.3)

The photo below shows Bor and Eugenia on rollerblades. Your goal is to use the physical quantity you've come up with in the previous experiment to make a prediction of the ratio of Bor's and Eugenia's speeds after Eugenia pushes Bor. Bor's mass is 70 kg and Eugenia's mass is 54 kg.

a. What is the physical quantity (that stays the same for a system before and after a collision) that you are using to make this prediction?

b. Use this quantity and information provided to make a numerical prediction of the ratio of Bor's and Eugenia's speeds after Eugenia pushes Bor.

c. Run the video [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-6-2-3] and take appropriate measurements by stepping the video frame by frame. Record and tabulate your data appropriately. Include estimates of the uncertainties of your measured quantities.

How do we define the momentum of a system?

What is the mathematics of this expression?

Different meaning of multiplication!!!!

What do we know of the momentum of a system where objects interact only with each other?

What if we take Bor as system? His momentum changes.

Why does his momentum change?

Is the force the only reason for the amount of the momentum change?

Read interrogate the text on the following slide to answer this question.

Impulse due to a force exerted on a single object

When you push Bor you exert a force on it, causing Bor to accelerate. The average acceleration $\vec{a}$ is defined as the change in velocity $\vec{v}_f - \vec{v}_i$ divided by the time interval $\Delta t = t_f - t_i$ during which that change occurs:

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t_f - t_i}$$

We can also use Newton's second law to determine an object's acceleration if we know its mass and the sum of the forces that other objects exert on it:

$$\vec{a} = \frac{\Sigma \vec{F}}{m}$$

We now have two expressions for an object's acceleration. Setting these two expressions for acceleration equal to each other, we get

$$\frac{\vec{v}_f - \vec{v}_i}{t_f - t_i} = \frac{\Sigma \vec{F}}{m}$$

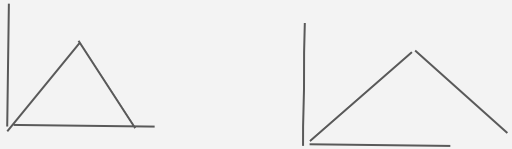
Now multiply both sides by $m(t_f - t_i)$ and get the following:

$$m\vec{v}_f - m\vec{v}_i = \vec{p}_f - \vec{p}_i = \Sigma \vec{F}(t_f - t_i) \tag{6.4}$$

Team 1 OALG 6.3.2 and b only [OALG Chapter 6 Final .docx]

a. Use your knowledge of impulse to explain the motion of the carts (specifically, identify the object that exerts the impulse on the carts) and to predict the shape of the velocity-vs-time graphs in the following experiments https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-3-2a

Constant F(x). since v(x) vs. t is a straight line



b. Watch the video at https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-3-2b to compare your prediction to the outcome. Discuss the differences if any occurred.

Team 2 OALG 6.3.2 and b only [OALG Chapter 6 Final .docx]

a. Use your knowledge of impulse to explain the motion of the carts (specifically, identify the object that exerts the impulse on the carts) and to predict the shape of the velocity-vs-time graphs in the following experiments https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-3-2a

- System is the fan and the cart
- Air pushes on the cart

b. Watch the video at https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-3-2b to compare your prediction to the outcome. Discuss the differences if any occurred.

Team 3 OALG 6.3.2 and b only [OALG Chapter 6 Final .docx]

a. Use your knowledge of impulse to explain the motion of the carts (specifically, identify the object that exerts the impulse on the carts) and to predict the shape of the velocity-vs-time graphs in the following experiments https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-3-2a

The object that exert the impulse is the air.

The shape could be close to a triangle (vi = 0, reaches a maximum and then it slows down due to friction) Eugenia: These are very low friction carts

When the Air exerted a force on the cart for a longer time (vi=0, max was larger and then it slows down due to friction)

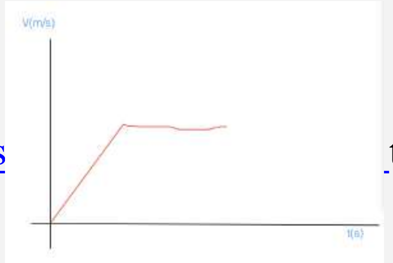
b. Watch the video at https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-3-2b to compare your prediction to the outcome. Discuss the differences if any occurred.

Team 4 OALG 6.3.2 and b only OALG Chapter 6 Final .docx

a. Use your knowledge of impulse to explain the motion of the carts (specifically, identify the object that exerts the impulse on the carts) and to predict the shape of the velocity-vs-time graphs in the following experiments https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-6-3-2a

The fan exerts a constant force on the air adjacent to the fan-cart, and the air exerts a constant force on the fan-cart (equal magnitude and opposite direction). The fan is pushing on the air by running for a period of time. The force multiplied by the time duration is the impulse that changes the momentum of the fan-cart.

GREAT!



b. Watch the video at https://mediaplayer.pearsoncmg.com/assets/_frames to compare your prediction to the outcome. Discuss the differences if any occurred.

All together OALG 6.3.3 OALG Chapter 6 Final .docx

When the system is isolated, its momentum is constant. If there are external forces exerted on the system, its momentum changes by the impulse. How do we combine those two ideas together?

$p_i + J = p_f$

Generalized impulse-momentum principle For a system containing one or more objects, the initial momentum of the system plus the sum of the impulses that external objects exert on the system during the time interval $(t_f - t_i)$ equals the final momentum of the system:

$$\underbrace{(m_1\vec{v}_{1i} + m_2\vec{v}_{2i} + \cdots)}_{\text{Initial momentum of the system}} + \underbrace{\Sigma\vec{F}_{\text{on Sys}}(t_f - t_i)}_{\text{Net impulse exerted on the system}} = \underbrace{(m_1\vec{v}_{1f} + m_2\vec{v}_{2f} + \cdots)}_{\text{Final momentum of the system}} \tag{6.8}$$

The x- and y-component forms of the generalized impulse-momentum principle are

$$(m_1 v_{1ix} + m_2 v_{2ix} + \cdots) + \Sigma F_{\text{on Sys }x}(t_f - t_i) = (m_1 v_{1fx} + m_2 v_{2fx} + \cdots) \tag{6.9x}$$

$$(m_1 v_{1iy} + m_2 v_{2iy} + \cdots) + \Sigma F_{\text{on Sys }y}(t_f - t_i) = (m_1 v_{1fy} + m_2 v_{2fy} + \cdots) \tag{6.9y}$$

Note: If the net impulse exerted in a particular direction is zero, then the component of the momentum of the system in that direction is constant.

Representing momentum-impulse process with bar charts

All together OALG 6.4.3 and 6.4.4 OALG Chapter 6 Final .docx

Team 1 OALG 6.4.5 OALG Chapter 6 Final .docx

Team 2 OALG 6.4.5 OALG Chapter 6 Final .docx

B. Describe what you observe. What is the difference between the two balls? What is the difference in the two experiments with the plank?

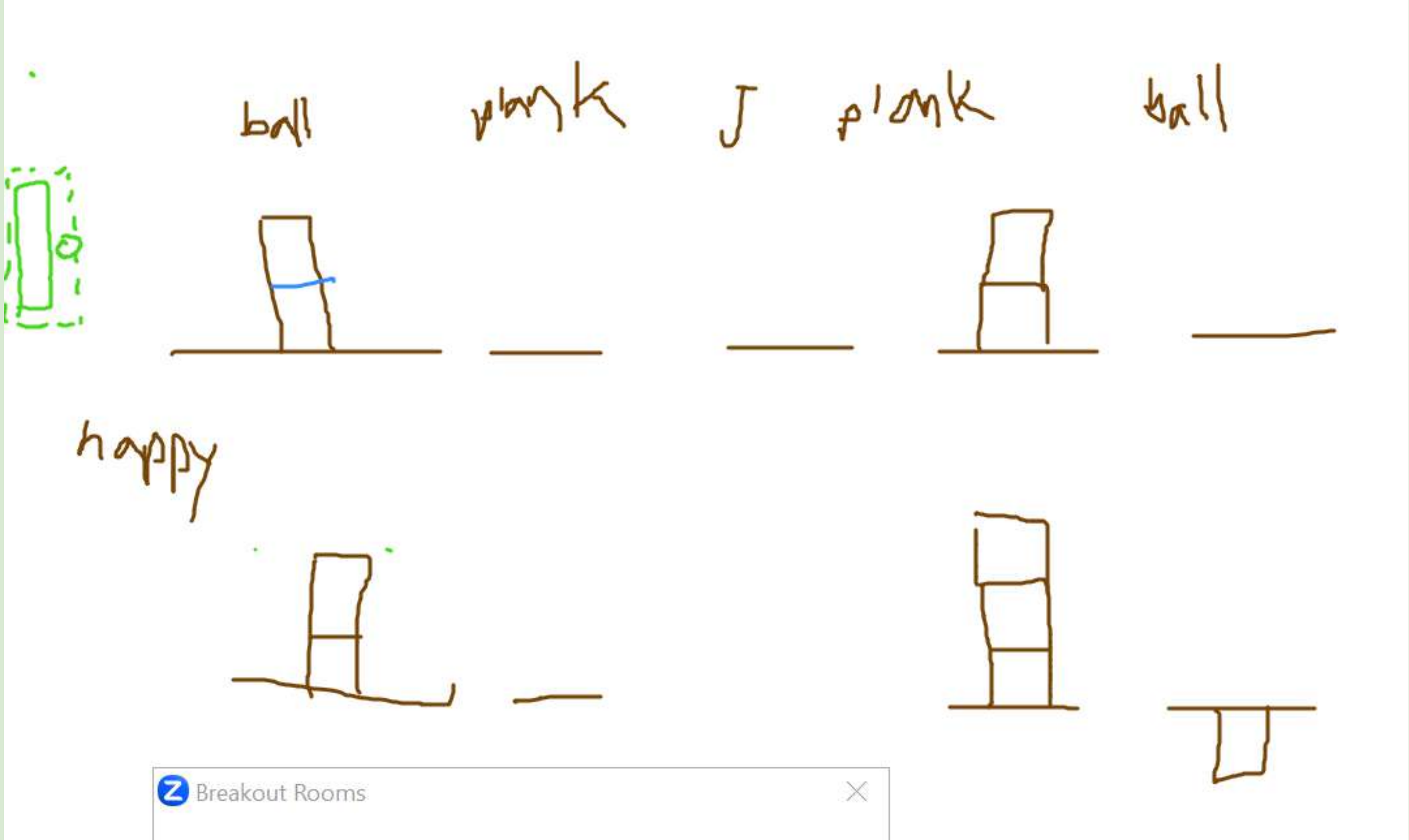
- Same mass (happy and sad ball) one is bouncy (knocks plank over), one is hard (does not knock the plank over)

c. Draw a bar chart for each of the collisions of the balls with the plank. First, choose the plank and the ball as the system and then repeat when the plank is the system. The initial state is right before the ball hits the plank and the final state is right after the ball hits the plank.

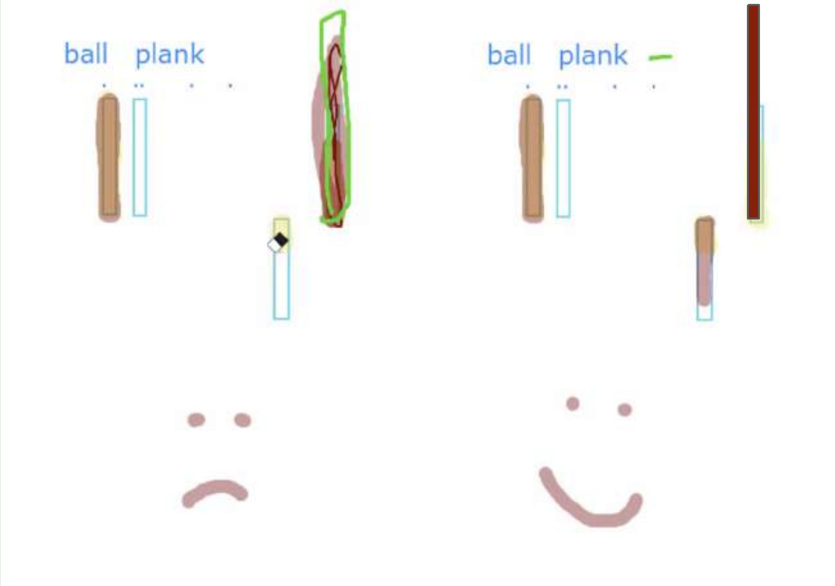
Ball and plank

d. Use the bar charts to explain the difference in the outcomes of the collisions. If you are having trouble, consult Example 6.3 in the textbook on page 158.

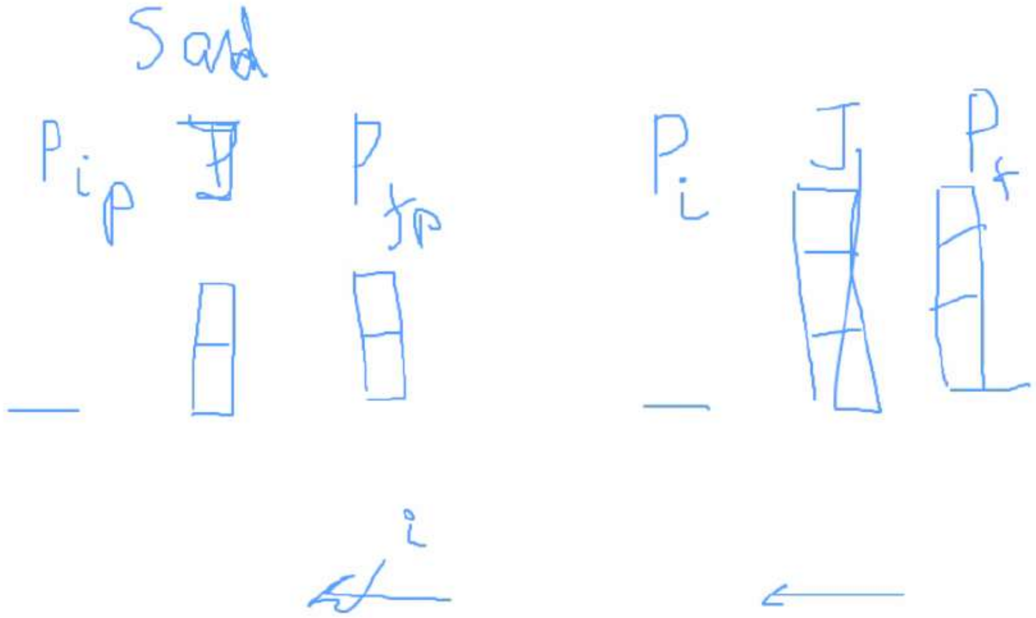
Team 3 OALG 6.4.5 OALG Chapter 6 Final .docx



Team 4 OALG 6.4.5 [OALG Chapter 6 Final .docx]



When is momentum conserved? When is it constant?



$\Delta p = -mv_{ix}$

$-2mv_{ix}$

All together OALG 6.4.6

Team 1 OALG 6.5.2 and 6.5.3

Team 2 OALG 6.5.2 and 6.5.3

Team 3 OALG 6.5.2 and 6.5.3

Team 4 OALG 6.5.2 and 6.5.3

Back to the need to know

What was our need to know? How can you explain the difference in the two experiments?

What did you learn today?

Difference between constant and conserved

I learned that momentum can be introduced as knowledge to the students from a simple experiment to analyze which quantities can be seen as constant, a nice way to show how money is constant, a way to logically deduce mv, then a way to introduce the momentum bars, how to use the bars in order to solve a problem like the one of the plank.A good example to interrogate the book.The use of constant in isolated systems, and then that momentum is always conserved. The most important is the flow of the critical items (wow and understanding) of the students.

Difference between constant and conserved.but still unclear.

The importance of a 'system' and the notion of isolated system

1) Conserved ≠ constant 2) Need to teach students how to read (interrogate a text) before they go to college 2a) why don't students read the text? 3) transition from thinking about the object that has changed in motion to Newton's 3rd law, and the idea of thinking about the mechanism for changing motion. 4) dopamine of problem solving, correctly predicting an outcome, and how that motivates students to continue learning.
Constant and conserved : momentum

Interrogate textbook in the right way

I learned how useful bar charts can be to help with conceptual understanding.

I learned that we can teach momentum first, then impulse, using "need to know" motivation..

Give always the student the opportunity to feel the enthusiasm that what they just learned works!

Difference between constant and conserved & Define isolated system vs. non-isolated system

How to use an experiment as either a testing experiment, or an observational experiment