Name & Number (if applicable): ___________________________________

Unit 5 Learning Goals – Momentum

Goal Set 1:

Students will be able to qualitatively and quantitatively analyze the linear momentum of objects and systems.

4.0	I can analyze complex scenarios and problems involving the linear momentum of objects and systems.
3.0	I can qualitatively and quantitatively analyze the linear momentum of objects and systems. • This includes application of the law of conservation of linear momentum.
2.0	I can recognize, recall, and explain specific vocabulary and concepts including: • Mass, weight, systems, inertia, momentum, law of conservation of momentum I am able to… • Distinguish objects from systems. • Distinguish inertia from momentum. • Calculate the linear momentum of an object. • Calculate the linear momentum of a system. • Identify that linear momentum transfers from one object to another during an interaction.
1.0	With help, partial success at 2.0 content

Check yourself:

Level 2.0

1.) Define mass and define weight. Give units for both.

2.) Define linear momentum.

3.) Circle the right answer for each sentence as you think to yourself: “I know that a mountain/a flying butterfly has more momentum. I also know that a mountain/a flying butterfly has more inertia. I am amazing/ awesome.”

4.) A 220 kg Bengal tiger moves in a straight line with a velocity of 1.5 m/s. What is its linear momentum?

5.) Two balls roll toward each other as follows: Ball A has a mass of 2 kg and a velocity of 2 m/s. Ball B has a mass of 4 kg and a velocity of -4 m/s. What is the total momentum of the system of Ball A and Ball B?

6.) When the two balls in question 5 collide, which of the following statements are true?

a. Ball A will transfer some of its momentum to Ball B. Truth Lies!!!
b. Ball B will transfer some of its momentum to Ball A. Truth Lies!!!
c. Ball A could slow down. Truth Lies!!!
d. Ball A could stop. Truth Lies!!!
e. Ball A could bounce backward. Truth Lies!!!
f. Ball B could change its motion, too. Truth Lies!!!

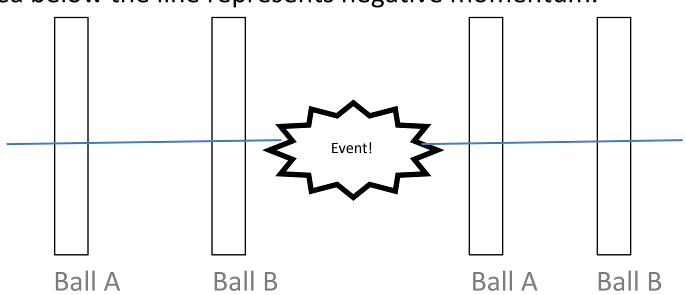
Level 3.0

Refer back to question 5 from level 2.0. Let's assume that Ball B's velocity changes to -2 m/s immediately after the collision.

1.) What is the total momentum for the system after the collision? (*Hint: You don't have to use your calculator for this.*)

2.) What is the final velocity of Ball A immediately following the collision?

3.) Draw the "momentum bars" for this interaction. The horizontal line through the middle of the bars represents zero momentum, the area above the line represents positive momentum, and the area below the line represents negative momentum.



Level 4.0

This question involves a collision that is not linear but is, instead, two dimensional. The rule for the conservation of linear momentum is that it is conserved in each dimension. For example, a two-dimensional collision in the x-y plane requires horizontal momentum to be conserved AND vertical momentum to be conserved. The trick is to break each initial and final momentum into its vertical and horizontal components and proceed from there solving two equations: one conserving horizontal momentum, and one conserving vertical momentum. At the end simple vector addition allows you to find the final answer. Here's a sample problem: A particle traveling upwards at 10m/s at an angle of 30^o to the horizontal collides with a particle moving downward at an angle of 20^o to the horizontal with a velocity of 12m/s. Afterwards the second particle moves at an angle of 40^o above horizontal with a velocity of 10m/s. Both particles have the same mass. What is the final velocity of the second particle?

Goal Set 2:

Students will be able to analyze the kinetic energy of objects and systems when interactions occur between the objects in those systems.

<table>
<tr><td>4.0</td><td>I can analyze the kinetic energy of objects and systems when complex interactions occur between the objects in those systems.</td></tr>
<tr><td>3.0</td><td>I can analyze the kinetic energy of objects and systems when interactions occur between the objects in those systems.</td></tr>
<tr><td>2.0</td><td>I can recognize, recall, and explain specific vocabulary and concepts including:
Energy, mechanical energy, kinetic energy, systems, linear momentum, law of conservation of momentum, velocity.
Elastic, totally inelastic, inelastic collisions.
I am able to…
Calculate kinetic energy and linear momentum of objects and systems.
Identify whether an interaction is elastic, totally inelastic, or inelastic based on its characteristics and behaviors.</td></tr>
<tr><td>1.0</td><td>With help, partial success at 2.0 content</td></tr>
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Check yourself:

Level 2.0

1.) Distinguish a closed system from an open system.

2.) A 3 kg object moves at 4 m/s. It collides with a 2 kg object that moves at -2 m/s.

a. What is the initial system momentum?

b. The final system momentum is (greater/less/equal to) your answer in part (a). If it cannot be determined, draw a flower here:

c. What is the initial system kinetic energy?

d. The final system kinetic energy is (greater/less/equal to) your answer in part (a). If it cannot be determined, draw a turtle here:

3.) Identify the following collisions as elastic, totally inelastic, inelastic, or "can't tell."

a. A red ball moves toward a dolphin's nose. The dolphin bounces the ball back to the person who threw it. A small sound is heard from the collision, and there is a little friction.

b. A red ball moves toward a child riding a camel. The girl catches the ball.

c. A person is playing pool and sends the cue ball into the seven ball. There is a sound but very little friction. The cue ball comes to a rest, and the seven ball moves into the pocket where the person had been aiming.

d. Two imaginary disks on an imaginary air hockey table collide and bounce apart, emitting no sound, creating no deformity in the disks, and creating no significant friction.

e. A collision happens in which total system momentum is conserved.

f. A collision happens in which total system kinetic energy is conserved.

g. A collision happens in which total system kinetic energy is not conserved.

Level 3.0

A person in an angry mob tosses a rotten 0.32 kg tomato at a politician.[1] The tomato misses[2] and, while moving at 3.5 m/s, strikes a 25 kg baby carriage.[3] The tomato splatters and bounces backward at -0.27 m/s, and the carriage moves forward.

1.) What is the velocity of the carriage after what became known as "The Incident"?

2.) What was the initial kinetic energy in the system?

3.) What was the final kinetic energy in the system?

4.) What percentage of the system's original kinetic energy, if any, was lost during the collision?

5.) What classification of collision type was this?

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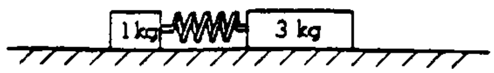
[1] Don't ever do this. It's rude and potentially dangerous. It's also assault, which is illegal. Overall it's a dumb move. Perhaps a little deep breathing would have helped our angry mob member to cope with anger.

[2] Thankfully

[3] See what can happen? I'll let you know that the baby was not, at the time, in the carriage, having cried incessantly for fifteen minutes to be picked up and held.

Level 4.0

A massless spring is between a 1 kilogram mass and a 3 kilogram mass as shown, but is not attached to either mass. Both masses are on a horizontal table. In an experiment, the spring is compressed. The 3 kilogram mass is then released and moves off with a speed of 1 meters per second. The 1kg mass also moves. There is with the table, but there is no friction between the spring and the blocks. (a) How much mechanical energy is released from the system in the form of thermal energy if the spring force constant is 2500N/m and the spring is initially compressed 0.09m? (b) Could you also then find the friction force? Provide a narrative answer.



Goal Set 3:

Students will be able to utilize the impulse-momentum theorem to analyze interactions between objects.

4.0	I can utilize the impulse-momentum theorem to analyze complex interactions between objects.
3.0	I can utilize the impulse-momentum theorem to analyze interactions between objects.
2.0	I can recognize, recall, and explain specific vocabulary including: • Velocity, acceleration, mass, net external force, impulse, momentum, impulse-momentum theorem. I am able to… • Distinguish objects from systems. • Explain Newton's second law. • Perform calculations involving changes in an object's momentum. • Perform calculations involving impulse. • Perform calculations involving the equivalence of impulse on an object and the resulting change in the object's momentum.
1.0	With help, partial success at 2.0 content

Check yourself:

Level 2.0

1.) Define impulse both in words and semi-quantitatively (i.e., using variables.)

2.) Explain how impulse relates to Newton's second law and to changes in momentum. You can do this semi-quantitatively and/or narratively. (*Hint: This was in our notes.*)

3.) A softball bat hits a 0.198 kg softball. The softball was initially traveling at 33 m/s (about 75 miles per hour – This is fastpitch, natch.) The bat applies 148 N of force to the ball and is in contact with it for 0.072 seconds.
    a. What impulse does the bat give to the ball?

    b. What will the ball's change in momentum be due to being hit by the bat?

    c. How fast will the softball travel as it leaves the bat?

Level 3.0

1.) In the previous problem (level 2.0 question 3)…
   a. If we look at the impulse-momentum theorem, are we looking at the ball-bat-person system, or are we looking at the ball itself as a single object being acted on by an outside source? (Check one.)
      - It is a ball-bat-person system.
      - The ball is an object being acted on by an outside source (the bat-person.)
   b. If we look at this situation from the law of conservation of momentum instead of the impulse-momentum theorem, would we consider the ball-bat-person system, or would we consider the ball itself as a single object being acted on by an outside source?
      - It is a ball-bat-person system.
      - The ball is an object being acted on by an outside source (the bat-person.)

2.) If a batter wants to hit a homerun, she should hit the ball with a (large/small) force and stay in contact with the ball for a (long/short) time to (increase/decrease) the impulse. This will (increase/decrease) the change in the ball's momentum.

3.) If a gymnast wants not to get hurt during a maneuver, he uses a mat because the mat will change his momentum over a (long/short) time, thereby (increasing/decreasing) the force required to change his momentum. This will (increase/decrease/have no effect on) the impulse.

Level 4.0

A two-car train moves along a straight track with a velocity of 1.5 m/s. Consider both cars to be rigid and symmetrical. Also consider the connecting link between the cars to be rigid. Car A's mass is 2000 kg, and Car B's mass is 4000 kg. (a) What is the momentum of each car? Of the system of the two cars together? (b) What impulse is required to stop the *system*? (c) The train collides with a rigid bumper in a roundhouse. What force is required to stop the system in 1.9 seconds? (d) Generate an *accurate* graph to represent this situation. Put 3.0 seconds of time on the x-axis and graph both the system momentum and impulse on the system on the y-axis. Make the collision begin at 1.0 seconds. (Note: If we did not do the lab on the impulse-momentum theorem yet in class, then you may not know the shape of the impulse curve. Make a best guess on the shape, and I'll explain why the shape is as it is in class.)

Chart your Progress

Goal Set 3