



MS Physical Science: Forces-Collision Safety

The following learning activities were backwards planned to facilitate the development of students' knowledge and skills for mastery of this NGSS Performance Expectation. Not all of the dimensions and CCSS are covered in the following activities and teachers are encouraged to address them where possible.

MS-PS2-1 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- MS-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.*** [Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.]

The performance expectation above was developed using [the following elements from the NRC document *A Framework for K-12*](#)

Science Education:

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Apply scientific ideas or principles to design an object, tool, process or system.

PS2.A: Forces and Motion

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

--- Connections to **Engineering, Technology, and Applications of Science**

Influence of Science, Engineering, and Technology on Society and the Natural World

- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

Connections to other DCIs in this grade-band:

MS.PS3.C

Articulation of DCIs across grade-bands:

3.PS2.A ; HS.PS2.A

Common Core State Standards Connections:

ELA/Literacy -

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. (MS-PS2-1)

RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. (MS-PS2-1)

WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-PS2-1)

Mathematics -

MP.2 Reason abstractly and quantitatively. (MS-PS2-1)

6.NS.C.5 Understand that positive and negative numbers are used together to describe quantities having opposite directions or values;



	<u>use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (MS-PS2-1)</u>
6.EE.A.2	<u>Write, read, and evaluate expressions in which letters stand for numbers. (MS-PS2-1)</u>
7.EE.B.3	<u>Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form, using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. (MS-PS2-1)</u>
7.EE.B.4	<u>Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. (MS-PS2-1)</u>

MS Physical Science –Forces – Collision Safety

	What Causes Motion?	How is force measured?	Force Diagrams	Newton's 3 rd Law
Student Experience	Students will observe different objects with different masses and predict which object will travel the furthest after an equal force is applied to each object. Based on their observations they will derive a pattern or 'law' that is supported by their observations.	Students create their own force meters using an elastic material (from the T4T cart) and calibrate them by hanging known masses and utilizing Newton's 2 nd law to quantify force.	Using the information they have learned and the force meters they have created students will create free body diagrams for a single object to show how much force is required to overcome the friction force.	Students will observe Newton's 3 rd law using their force meters to see that as you apply a force in one direction there is an equal and opposite force being applied which they will create a free body diagram.
T4T Material	Round objects with different mass, force apparatus, "plastic brains", corrugated plastic	Elastic material from cart, vinyl window blind, set of weights	Force meter, mass, small wood blocks, friction fabric tiles	Force meters
Big Idea	Newton's 1 st Law. An object in motion will continue in motion with constant velocity unless acted upon by a net external force.	Newton's 2 nd Law. $F_{\text{net}} = ma$. Weight: $F_g = mg$	Balanced v Unbalanced forces Free body diagrams	Newton's 3 rd law
Connection to Culminating Activity	In order for any object to change its motion (to accelerate or decelerate) a force must be applied, such as gravity pulling the egg car down a ramp.	Students will need to know that force can be quantified in Newtons and that gravity is one of the major forces acting on the egg car	Students will need to know how to create free body diagrams in order to communicate the amount of force being applied to the egg and wall	During a collision the force applied to the egg car will be equal and opposite.
CA Standards	CA8.2.e CA8.2.f	CA.8.2.d CA8.2.g	CA.8.2.a CA.8.2.c CA.8.2.d	CA.8.2.a CA.8.2.b CA8.2.d



	Collisions with stationary objects	Research and Development	Egg Jousting
Student Experience	Students will be introduced to the egg car, ramp, and shown the collision of the egg at several different heights, establishing the force needed to break the egg. Students will begin to research how the force transferred to the egg can be distributed/ reduced.	Students continue to research different types of safety systems that may prevent injury, build their egg cars and test.	Students compete against one another to see who had created the safest egg car
Material	Egg car chassis, ramp, heavy stationary object, eggs, dummy eggs ,plastic bags	Egg car chassis, ramp, heavy stationary object, eggs, dummy eggs, plastic bags, various t4t materials for students to build	Egg car chassis, ramp, heavy stationary object, eggs, dummy eggs, plastic bags
Big Idea	Students establish that the lower the egg launch height the less force is transferred to the egg, the higher the launch height the more force is generated which is then imparted to the egg during the collision	Students begin research and build their egg cars so that they can mitigate the amount of damage done to the egg car, students must demonstrate their logic in their build design.	Students will have an opportunity to see what type of safety systems were the best by competing against one another.
Connection to Culminating Activity	The egg ramp will be used to demonstrate how much force is being applied to the egg and will allow students to see how much force they are trying to protect the egg from	Culminating Activity	Culminating Activity
CA Standards	CA.8.2.a CA.8.2.b CA8.2.d	CA.8.2.a-f	CA.8.2.a-f



Science Practices:

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.
- Students will be using a model of Newton's Third law, that demonstrates that there is an equal and opposite force to every reaction. As the amount of force applied by the egg car increase, the equal and opposite force from the wall is also increasing which in turn will break the egg.

Engineering Practices:

Constructing Explanations and Designing Solutions

- Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.
- Apply scientific ideas or principles to design an object, tool, process or system.
- Students will be designing a solution to minimize the amount of force that is being transferred to the egg from the collision.

Prior Knowledge:

Students will have completed the motion unit, in which they have studied reference point, measuring motion, and calculating speed. This unit will next unit will focus on forces and Newton's laws as they are used to describe force.



Activity Guide for Forces Unit

1. What causes motion?

Objective: Students are able to explain that in order for an object to move, accelerate/ decelerate, a force must be applied and as the mass of the object increases more force is required. (Newton's 1st Law)

Engage

1. Students are asked to observe several demonstrations of movement and are asked to write down what they have in common. Think-Ink-Pair-Share activity
 - a. "Silently observe the following demonstrations and write down any observations that you have for each of them"
 - i. Time permitting this may be setup as stations rather than a demonstration
 - b. Students observe several different objects in motion, a ball bouncing, a car rolling down a ramp, video of a train moving past another train, etc., and write down their observations for each of the demonstrations.
 - c. "Discuss with your partner what some of the observations you have and if there are any similarities between the different demonstrations."
 - d. Share out as a whole group
 - i. Get students to notice that all of the demonstrations have to do with motion
 - e. "What do you think causes things to move?"
 - i. Possible responses may include energy, pushing, pulling,
 - ii. All changes in motion comes from the result of a force, or a type of push or pull

Explore

2. Students given round objects with various masses, a golf ball, tennis ball, medicine ball, ping pong ball (stand ins for these materials can be used from t4t materials) etc, and are asked to record the mass of each of the objects and rank which objects will travel the furthest when an equal amount of force is applied to each of them.
 - a. "Based on the mass of the objects that you have recorded which of the objects do you think will travel the furthest when we hit it with a uniform, or the same amount, of force?"
 - b. Students share and write down their predictions
 - c. "What are some of the predictions that you have made? Why do you think that?"
 - i. Students may already make the connection to real life experience that it is a lot harder to move objects that are heavier
 - ii. Important to emphasize that the force hitting the objects is the same
 - d. Teacher uses force apparatus to propel each object forward and students record the distance traveled by each object and any pattern they notice.
 - i. "Which objects traveled the furthest? Was there any pattern that you noticed?"
 - e. Student share out what they noticed as the mass increase the objects tend to travel a smaller distance.

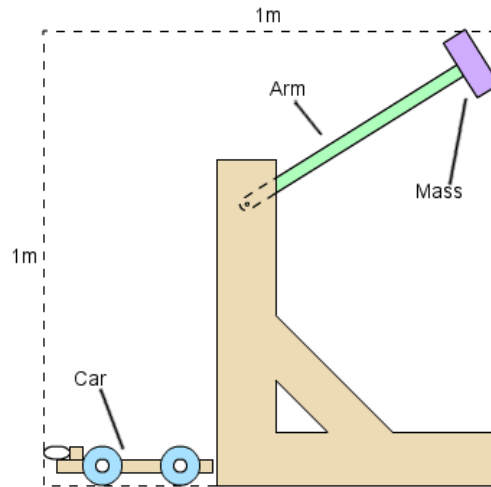


Fig 1: Example of Force Pendulum

Source: <http://scioly.org/wiki/index.php/Scrambler>

Explain

3. Teacher leads a discussion as to how the objects will not move unless there is a force applied to the object and the more massive an object, the more force is needed to get it to move, this is called the law of inertia also known as Newton's 1st law.
 - a. In order for an object to move, accelerate/decelerate, a force must act upon it
 - i. Introduce terminology of Newton's 1st law: An object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.
 - b. The more massive an object the more force is needed for it to get it to move, accelerate/decelerate.
 - c. The larger mass ball traveled a smaller distance because it required more force to get it to move, the lighter mass objects traveled further because they required less force to get it to move.

Elaborate

4. Teacher leads a discussion as to whether the opposite is true as well; does it take more force to stop an object with more mass?
 - a. "Do you think the opposite is true? Do you think that it takes more force to stop an object if it has more mass?"
 - i. Demonstrate by rolling the lighter mass ball to a student followed by the heavier mass ball

Evaluate

5. Show students a video of car collision with a crash test dummy inside not wearing a seatbelt, students describe why the crash test dummy continues to move even when the car has stopped using Newton's 1st law.



- a. Using Newton's 1st law, explain what happens to a crash test dummy when the car is in a collision.
- b. <https://www.youtube.com/watch?v=d7iYZPp2zYY>

2. How can we measure force?

Objective: Students will construct a force meter and calibrate it using Newton's 2nd law, demonstrating that force can be quantified.

Engage

1. Students are posed the question "Why do you think it would be important quantify, or measure, the amount of force acting on an object? How would you go about measuring force?" TIPS activity
 - a. Teacher can cite examples of car crash safety, helmets, submarines, astronauts in space, etc.
 - b. Students write their responses, share with partners and share out whole group.
 - c. "The first major force acting on all of us right now in this room is what?"
 - i. Students may say air pressure, heart beating, muscle forces, and gravity
 - ii. Introduce students to gravity
 - d. "One of the most influential forces here on earth is gravity, it impacts us in a very large way"
 - i. "Gravity is what causes us to weigh something, that's why on the moon we are almost weightless, there is less gravity pulling us down!"
 - ii. "Without gravity we are free to jump up, but it's not as fun because then you would never be able to come back down!"
2. Show students how much they would weigh on different planets.
 - a. <http://www.exploratorium.edu/ronh/weight/>
3. The measurement of weight is actually a measurement of force and how much gravity is pulling us down toward the earth.
 - a. Resource:
http://www.bbc.co.uk/bitesize/ks3/science/energy_electricity_forces/forces/revision/3/
 - b. "We are going to try and build a way of measuring the force of gravity"

Explore

4. Students are given the materials for a force meter and asked to try and figure out how they can measure how much force, gravity, is pulling down on the various masses.
 - a. Students are guided through the process of building the force meter, allowing students time to struggle with the materials and only scaffolding when needed (as permitted by time).

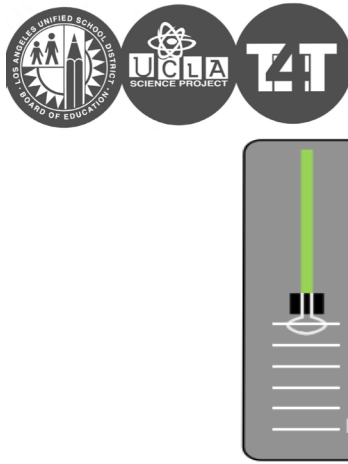


Figure X: Force meter

Source: T4T Forces-Glider Project

Explain

5. Explain to Students Newton's 2nd law, $F=ma$
 - a. Newton was able to figure out that force can be calculated from the mass and it's acceleration, when you multiply the mass by the acceleration, you get force.
 - b. The acceleration of gravity is 9.8 m/s^2
 - i. Gravity can be rounded to 10 if so desired by teacher

Elaborate

6. Based on Newton's 2nd Law, explain why an object falling under gravity would have more force than an object that has less mass?

Evaluate

7. Given the acceleration of gravity and a set of masses, students calibrate their force meters.

Resources: <https://www.youtube.com/watch?v=WzvhuQ5RWJE>

3. Balanced and Unbalanced Forces

Objective: Using force meters created by students, students will investigate balanced and unbalanced forces by pulling a mass across different surfaces

Engage

1. Based on Newton's 1st law, students explain why an object on the table rests on the table.
 - a. Students will cite that an object at rest will stay at rest, etc
 - b. Teacher proposes the fact that there is a force acting on the object as described in the previous activity, gravity
 - c. "So why is the object at rest if we said that there is force acting on it?"
 - d. Have students brainstorm what may be happening to keep the object at rest if there is force acting on it.
 - i. Additional examples can be pushing against a wall, sitting in a chair, standing on the ground.



- ii. If we are applying a force why is it that the objects are not moving?

Explore

2. In order to explore this idea students are given a container with a mass that is held constant and are asked to pull the mass across several different surfaces with various amounts of friction.
 - a. Students pull the mass across several different textured surfaces, ice, a desk, sand paper, etc.
 - b. Students record their observations and any patterns that they may have noticed

Explain

3. There are many different types of forces that are acting on an object at a single time, in order to determine whether an object is going to move or not move is dependent on the sum of those forces.
 - a. An object will only move if the forces acting on it are unbalanced
 - b. When an object is at rest on a surface there is the normal force that is perpendicular to it, hence objects are able to rest on surfaces and not fall through.
 - c. On earth there is always a friction force that is opposing the applied force
4. These forces can be communicated using free body diagrams

Elaborate

5. Based on what the students have learned they must now create relatively accurate free body diagrams for the different textured surfaces.
 - a. The diagrams should show that as the amount of friction increased the amount of force needed to get the object to move increased.

Evaluate

6. Students can be provided a problem set of various free body diagrams in which they predict whether an object will move or not and what direction they will move in.

4. Newton's 3rd Law of Motion

Objective:

Engage

7. Place two students in rolling chairs and have them face one another. Before having the students push against one another, ask the students to predict what will happen.
 - a. Have students make predictions and share with one another
 - b. Students should support their prediction with what they know about balanced and unbalanced forces.
8. Have only one student push against the other student's hands while the other keeps their arms locked into position.
 - a. If only one of the students pushed, why do both students move an equal distance apart?



Explore

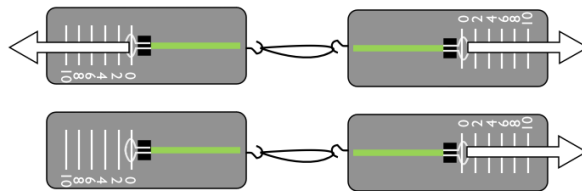
9. With a partner, create four examples of an object applying a force on another object and predict how they objects will move
 - a. Keep in mind the mass of the object and the amount of force that is being applied.
 - b. Draw a force diagram for the forces that will be acting on each of the objects

Explain

10. Explain to students Newton's 3rd law and how for every reaction there is an equal and opposite reaction.
 - a. This concept can sometimes be hard for students to grasp, some great videos can be found here:
 - i. https://www.youtube.com/watch?v=cP0Bb3WXJ_k
 - ii. <http://science360.gov/obj/video/d0e16d27-05d4-4511-9394-2758aa066981/science-nfl-football-newtons-third-law-motion>
 - iii. <https://www.youtube.com/watch?v=8bTdMmNZm2M>

Elaborate

11. Have students pair up with their force meters and have them hook the force meters together. Keeping one of the force meters stationary, pull on the opposite meter.
 - c. Students record their observations
 - i. Force meters should read the exact same measurement of newtons
 - ii. Students create accurate free body diagrams that show equal and opposite forces acting on each of the force meters.



*Figure: Example of fore meters with force being applied
Source: T4T Forces-Glider Project*

Evaluate

12. Students observe a video of a golf ball striking a steel plate at 150 mph and have to explain the forces that are acting on the ball based on Newton's Laws.
 - d. <https://www.youtube.com/watch?v=AkB81u5IM3I>



5. Collisions with a Stationary Object

Objective: Students will see the ramp being used for the culminating activity and will be asked to being research on how they can mitigate the force transferred to the egg in the collision.

Engage

1. Show students a collision of car with a stationary object, or helmet with a stationary object and ask them to describe why they think collisions can be so harmful?
 - a. “Based on Newton’s Laws, why do you think collisions can be so harmful?”
 - b. TIPS
 - c. Scaffolding can be provided, “an object in motion will stay in motion, what object are in motion when a car is traveling, what happens when the car stops abruptly, what about in a helmet, or a skull, if that stops abruptly what will happen to the brain?”
2. Share with students that they will be investigating how we can make cars or helmets safer by minimizing the applied force to the occupant of a car or to the brain.

Explore

3. Students are shown the ramp that they will be using to test the safety design that they are able to come up with in order to mitigate the damage done in a collision.
4. Show students the egg car and ask them to draw the forces they think will be acting on the egg
 - a. at the top of the ramp, at the bottom of the ramp and during the collision.

Explain

5. Teach mini-lecture on Newton’s 3rd Law. At the collision the force hitting the wall is equal to the force hitting the egg.
6. Establish the height of the launch where the egg will break without any safety measures, this will be the testing line.
7. Introduce the constraints of building the egg car
 - a. Students are allowed to add things to the front of the car and the chassis as long as they do not interfere with the rolling of the car
 - b. Safety mechanisms must be easily removable from the chassis to allow students to use the test car

Elaborate

8. Allow student the opportunity to research how collisions work and how cars and helmets are designed and able to reduce the amount of damage inflicted by the force of the collision.
 - a. Resources:
 - i. How Air bags work: <http://auto.howstuffworks.com/car-driving-safety/safety-regulatory-devices/airbag.htm>
 - ii. How Seat belts work: <http://auto.howstuffworks.com/car-driving-safety/safety-regulatory-devices/seatbelt.htm>
 - iii. How Crumple zones work: <http://auto.howstuffworks.com/car-driving-safety/safety-regulatory-devices/crumple-zone.htm>



iv. What happens to passengers:

http://www.rms.nsw.gov.au/geared/your_driving_skills/car_crashes/anatomy_of_a_crash.html

v. Three Collisions of a Car Crash: <http://buckleup.mt.gov/docs/three-collisions-in-crash.pdf>

9. Students will complete a blueprint of their idea explaining how they plan to control the amount of damage done to their egg.
 - a. Based on the blue print that the students complete they must support why they have chosen each feature of their design
 - i. How will each component of your design going to reduce the amount of damage done to the egg
 - ii. How are they related to Newton's Laws

Evaluate

10. Students must explain how their design will limit the amount of force transferred to the egg by utilizing their knowledge of Newton's Laws and the research they have conducted.

6. Development and Testing-Culminating activity

Objective: Students will begin to design, build, and test their egg cars to help mitigate the damage done by the collisions

Engage

1. Show students the egg car traveling down the ramp and remind them of their job of mitigating the damage done by the collision.

Explore

2. Using T4T materials students will design a safety device that will fit on top of the egg car chassis that will be able to keep the egg from cracking.

Explain

3. Guide Students toward creating crumple zones/padding in order to slow down the collision, the use of air bags to re direct the force, and the use of restraints to keep stop the forward movement due to inertia.

Elaborate

4. As students are creating their cars they will be able to start testing their safety devices using dummy eggs
 - a. Once students feel they have completed their task they will have the first round of crash trials.



- b. Allow students opportunities to retry and redevelop the safety devices they have put into place.

Evaluate

5. Students will be evaluated on the logic and execution of their design on the topics listed below; more detailed information is located in the Rubric on the next page.
 - a. Scientific knowledge
 - b. Plan
 - c. Construction
 - d. Function
 - e. Modification and testing



Building A Structure : Scramble Car

Teacher Name: **Mr. Payton**

Student Name: _____

CATEGORY	4	3	2	1
Scientific Knowledge	Explanations by all group members indicate a clear and accurate understanding of scientific principles underlying the construction and modifications.	Explanations by all group members indicate a relatively accurate understanding of scientific principles underlying the construction and modifications.	Explanations by most group members indicate relatively accurate understanding of scientific principles underlying the construction and modifications.	Explanations by several members of the group do not illustrate much understanding of scientific principles underlying the construction and modifications.
Plan	Plan is neat with clear measurements and labeling for all components.	Plan is neat with clear measurements and labeling for most components.	Plan provides clear measurements and labeling for most components.	Plan does not show measurements clearly or is otherwise inadequately labeled.
Construction - Materials	Appropriate materials were selected and creatively modified in ways that made them even better.	Appropriate materials were selected and there was an attempt at creative modification to make them even better.	Appropriate materials were selected.	Inappropriate materials were selected and contributed to a product that performed poorly.
Function	Structure functions extraordinarily well, holding up under atypical stresses.	Structure functions well, holding up under typical stresses.	Structure functions pretty well, but deteriorates under typical stresses.	Fatal flaws in function with complete failure under typical stresses.
Modification/Testing	Clear evidence of troubleshooting, testing, and refinements based on data or scientific principles.	Clear evidence of troubleshooting, testing and refinements.	Some evidence of troubleshooting, testing and refinements.	Little evidence of troubleshooting, testing or refinement.

7. Egg Jousting- Extra

Objective:

Engage

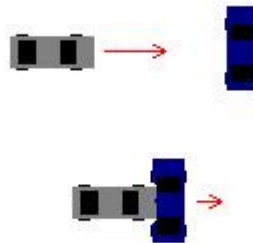
1. Not all collisions are stationary objects, sometimes cars hit each other and they have varying mass
 - a. Based on your knowledge of forces and motion, predict what will happen when more massive objects collide with less massive objects.
 - b. Will the force of the collision be the same for both objects? Why?
 - c. When the objects collide, what will happen to the object with more mass? To the object with less mass? Describe the motion of each and cite Newton's laws to support your prediction.

Explore

2. Students will have an opportunity to see how the egg car travels down the ramp to hit another egg car that is at the bottom of the ramp.
 - a. Students will make observations as to how the objects move
 - b. Did one object move or both objects move? How did they move?
 - c. How do you think the mass of the cars played a role in the movement?

Explain

3. Introduce students to the idea of elastic and inelastic collisions
 - a. Inelastic collisions
 - i. The collision of two objects where momentum is conserved but not kinetic energy



ii.

Figure 2: Inelastic Collision

Source: http://ffden-2.phys.uaf.edu/211_fall2002.web.dir/ben_townsend/TypesofCollisions.htm

- iii. The objects in an inelastic collision stick together and will travel in the same direction after the collision
- iv. Energy is converted into heat, sound, and the deformation of the object



b. Elastic collisions

- i. The collisions of objects where both momentum and kinetic energy is conserved
- ii. When two objects collide and “bounce” apart when they collide.

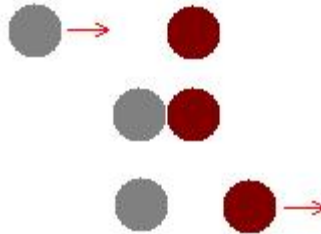


Figure 3: Elastic Collision

Source: http://ffden-2.phys.uaf.edu/211_fall2002.web.dir/ben_townsend/TypesofCollisions.htm

- 4. How does mass play a role in the collision of objects?
 - a. As the mass of the object increase so does the inertia, therefore the more massive the object the less it will move relative to less massive objects that will move more.
 - b. Show students the pHet Collisions Lab
 - i. <http://phet.colorado.edu/en/simulation/collision-lab>

Elaborate

- 5. Students will have an opportunity to see how their egg cars react when they collide and test to see who's safety mechanisms are the most effective.
 - a. Teams pair up and measure the masses of each of their cars and determine who will be at the top of the ramp and who will be at the bottom of the ramp.
 - b. Students predict how the objects will move and cite how Newton's laws influenced their predictions.
 - c. Students are given the opportunity to have their egg cars collide, recording the outcome and observing which types of collision restraints work the best.

Evaluate

- 6. Students will be evaluated on how they cite Newton's Laws to explain the motion of the collision in their predictions.