Module 5: Impulse and Momentum
Topic 4 Content: Momentum in Collisions Presentation Notes

Momentum in collisions

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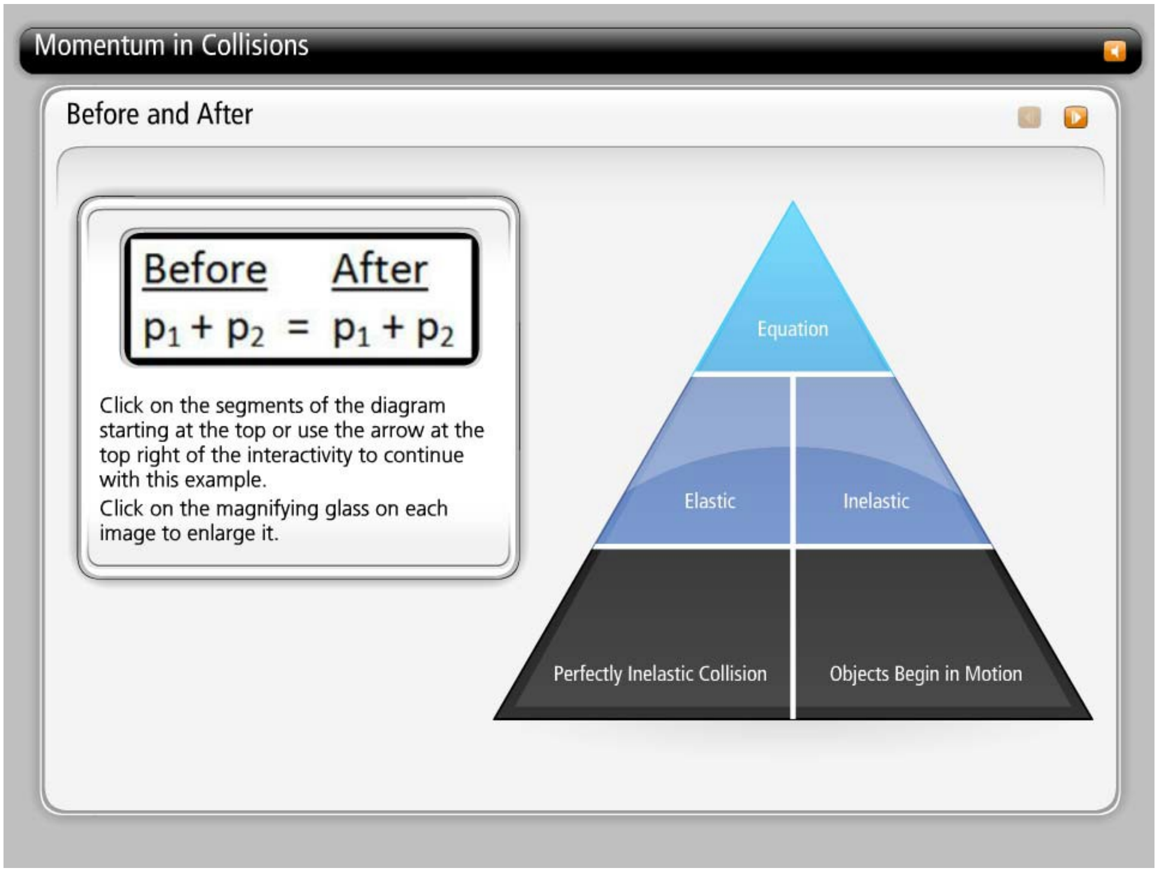
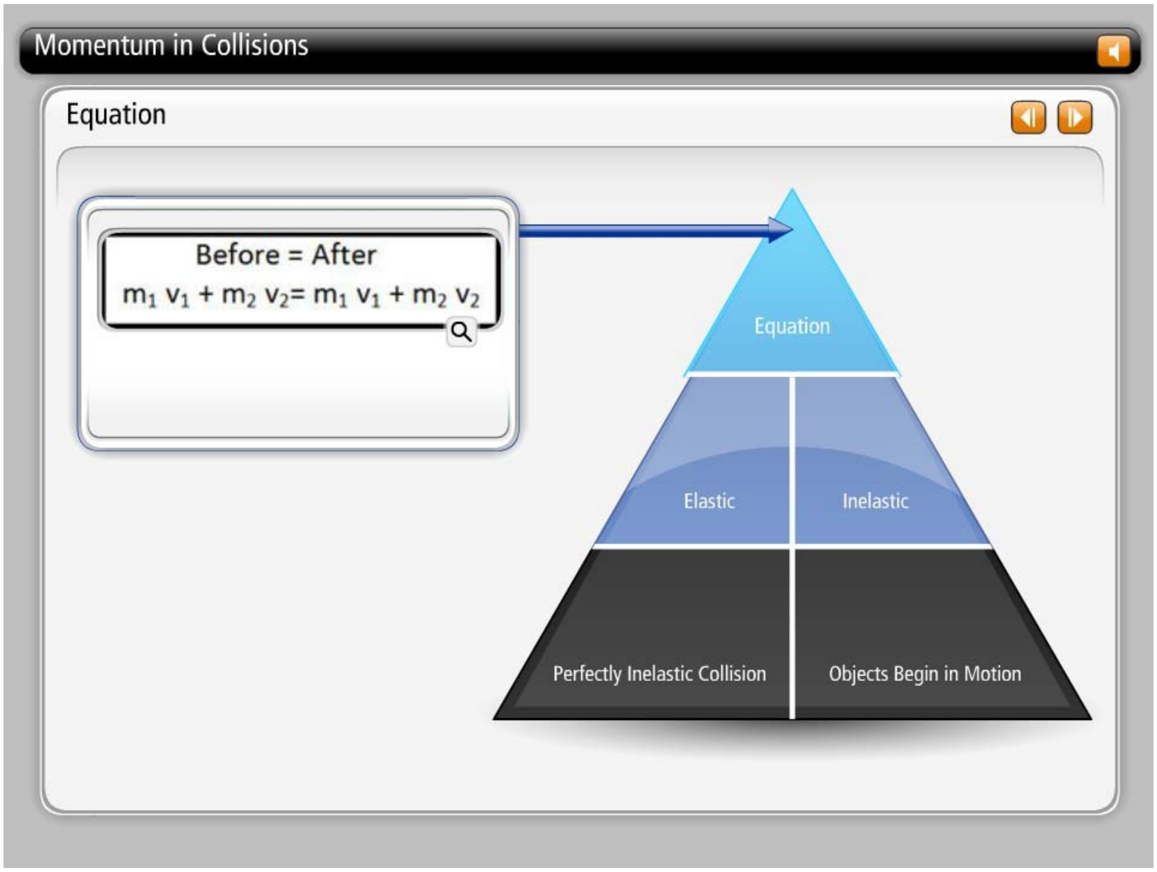


Before and After

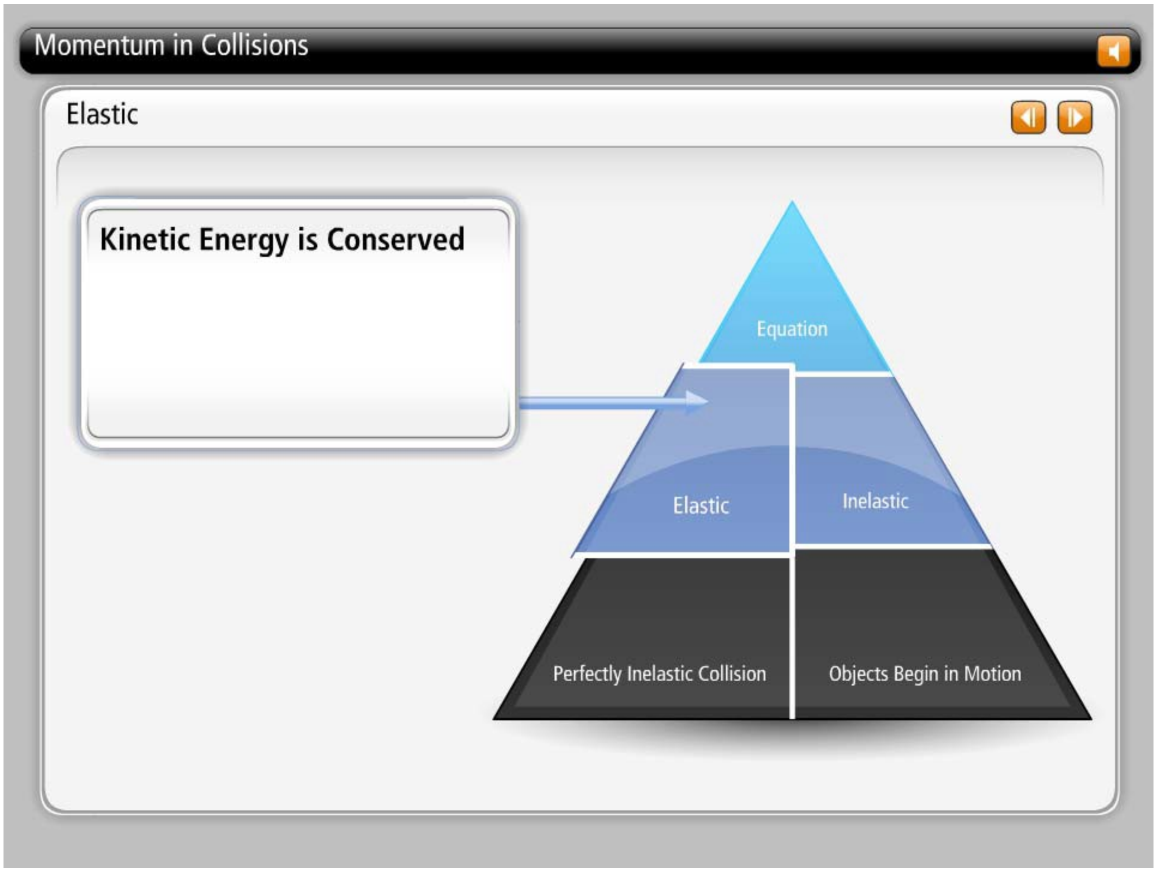
Since the change in momentum must be zero, this also means that the total momentum that exists before an interaction will be equal to the total momentum after the interaction. You can express this as an equation by writing p one plus p two before equals p one plus p two after, where p one and p two are the respective momentum of objects one and two, and before and after refer to before the interaction and after the interaction.



Equation

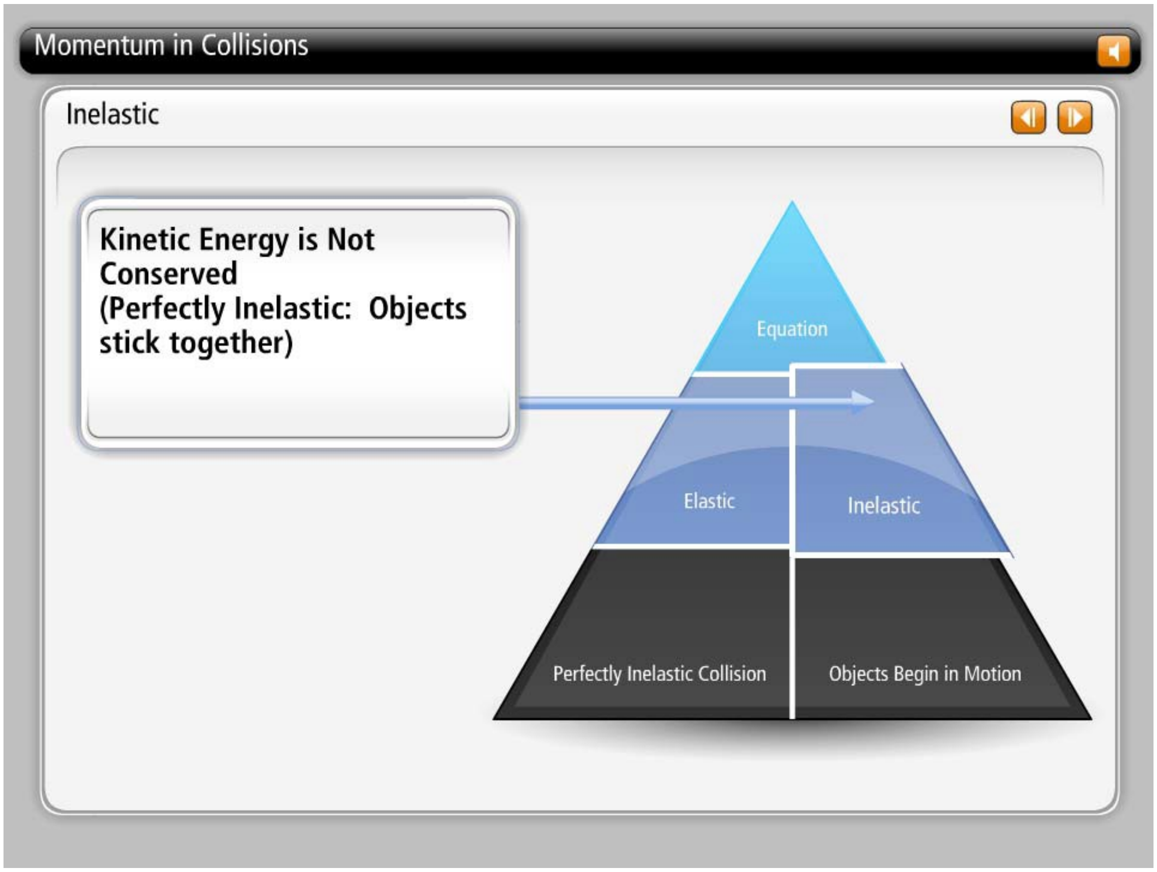
In all collisions, you can solve momentum problems by setting up an equation showing that the momentum before the collision equals the momentum after the collision. You write m one v one plus m two v two before equals m one v one plus m two v two after.

This equation will work for any collision, elastic or inelastic, since momentum is conserved. It will also work if both objects begin in motion or if one or both objects begin at rest.



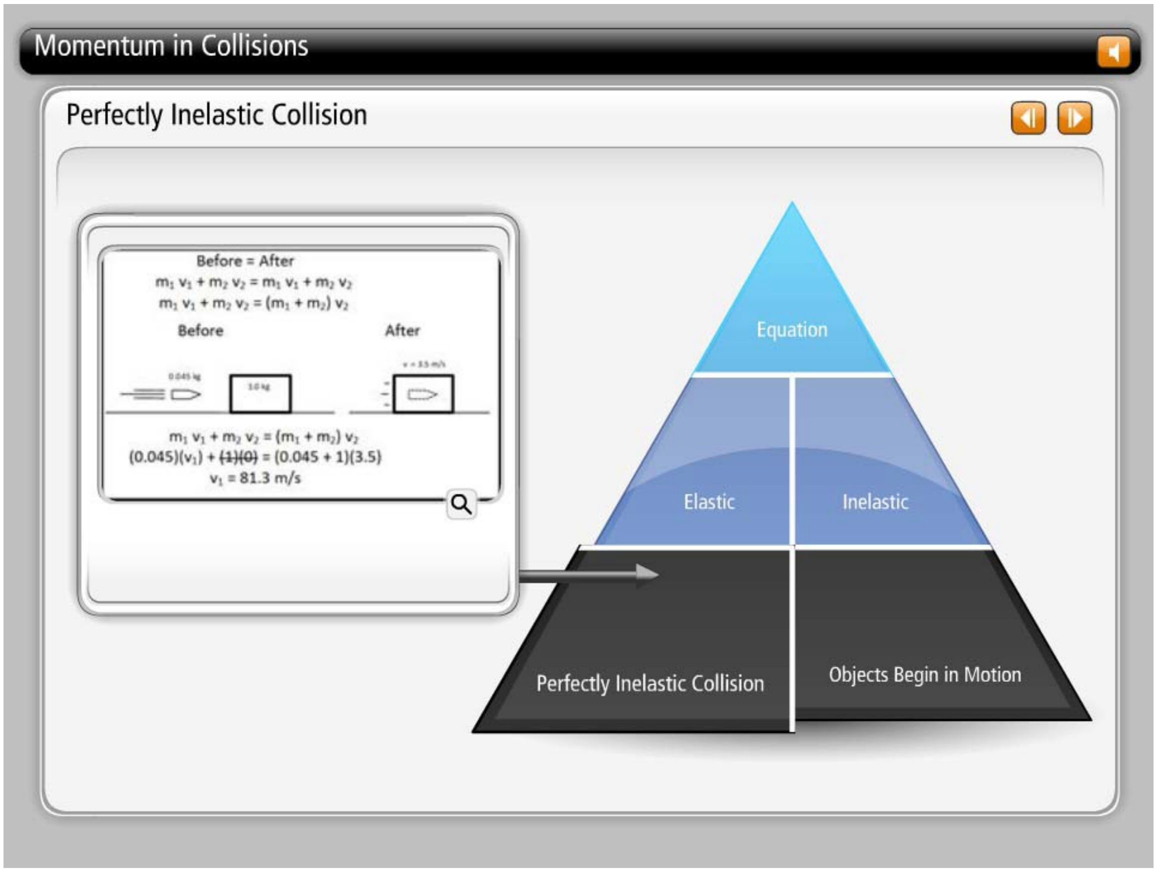
Elastic

Interactions other than explosions are generally categorized as collisions. Collisions can be of several types. They can be elastic or inelastic. Elastic collisions are interactions in which kinetic energy is conserved.



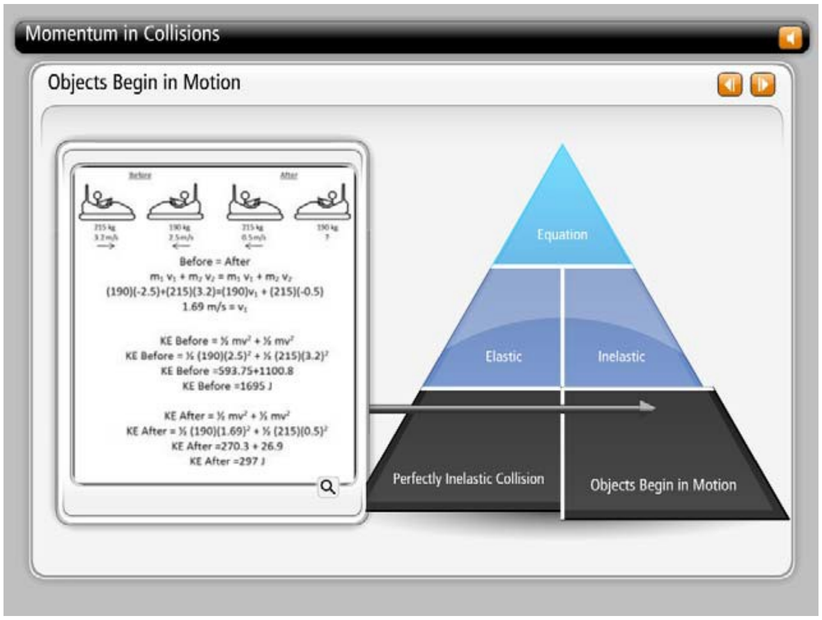
Inelastic

Inelastic collisions are interactions where kinetic energy is not conserved, as some kinetic energy is transformed into heat, sound or other mechanical vibrations, or is used as work deforming the object. Perfectly inelastic collisions are interactions where the interacting objects actually stick together.



Perfectly Inelastic Collision

In all collisions, you can solve momentum problems by setting up an equation showing that the momentum before the collision equals the momentum after the collision. You write m one v one plus m two v two before equals m one v one plus m two v two after. This equation will work for any collision, elastic or inelastic, since momentum is conserved. It will also work if both objects begin in motion or if one or both objects begin at rest. Let's start by looking at perfectly inelastic collisions. If the objects stick together, you should recognize that their velocities after the collision will be the same. You can therefore simplify our equation by saying that the mass of the first object times its velocity plus the mass of the second object times its velocity is equal to the sum of the masses times the combined final velocity. In order to determine the speed of a bullet, it is shot into a piece of wood initially at rest. The mass of the bullet is zero point zero four five kilograms. It is shot into a one point zero kilogram block of wood. After the bullet lodges in the wood, they move at a speed of three point five meters per second. What was the initial velocity of the bullet? Using the special-case equation for conservation of momentum in an inelastic collision, you can substitute the mass of the bullet, the mass of the block , the initial velocity of the block and the final velocity of the block and bullet. Solving the equation you see that the initial velocity of the bullet was eighty one point three meters per second.



Objects Begin in Motion

What about a situation in which both objects begin in motion?

Jane and Bobby head off to the amusement park and hop into the bumper cars. Jane and her bumper car have a combined mass of one hundred ninety kilograms and they are moving to the left at two point five meters per second. Bobby and his bumper car have a combined mass of two hundred fifteen kilograms and they are moving at three point two meters per second to the right as they hit Jane in a head-on collision.

After the collision, Bobby is moving to the left at zero point five meters per

second. What is Jane's speed and direction after the collision?

Was the collision elastic or inelastic?

First, you should set up our general equation that equates momentum before and after the collision.

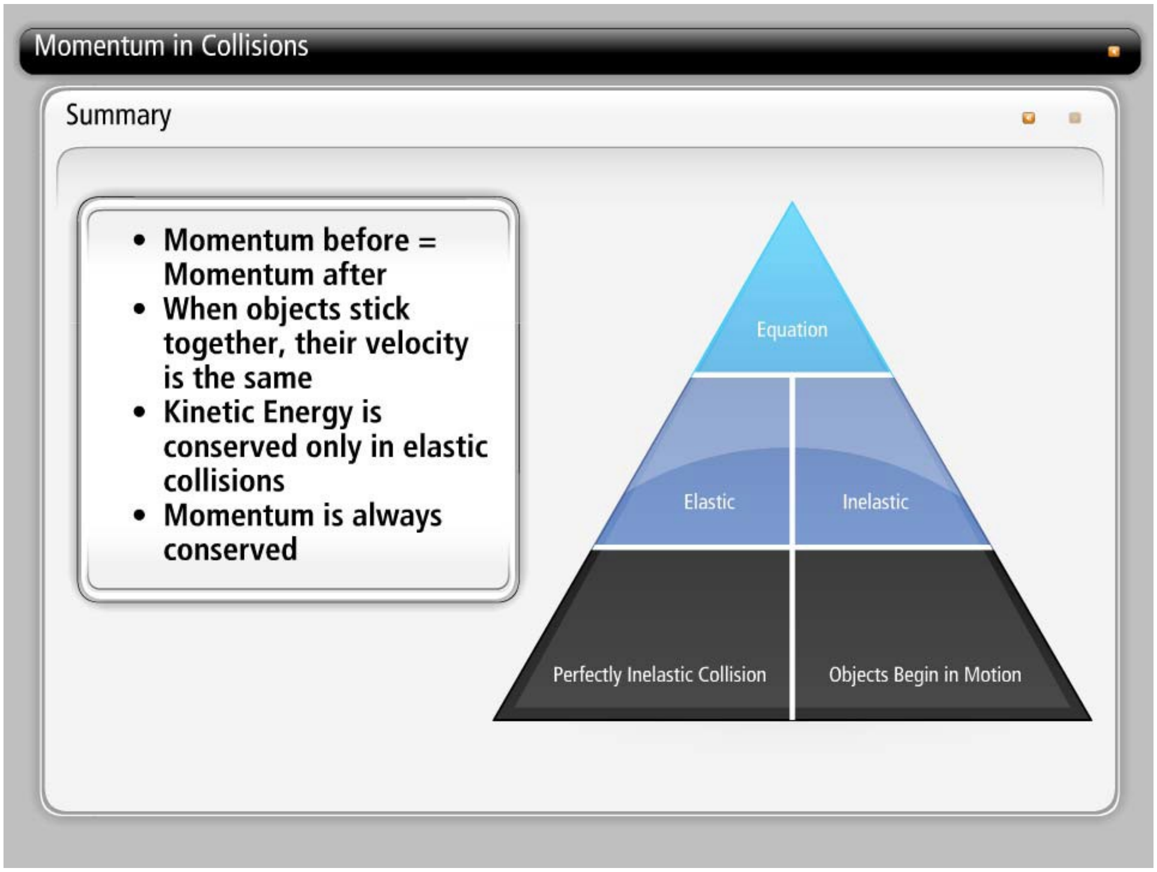
You will substitute Jane's values for m one and v one and Bobby's values for m two and v two and then solve for Jane's velocity after the collision. Velocities to the right will be positive and velocities to the left will be negative.

M one is Jane's mass, which is one hundred ninety kilograms. M two is Bobby's mass of two hundred fifteen kilograms. Before the collision, v one is Jane's velocity of negative two point five meters per second and v two is Bobby's speed of three point two meters per second. After the collision, you don't know v one, but v two is Bobby's speed of negative zero point five meters per second.

When you solve for v one, you see that Jane's speed after the collision is positive one point six nine meters per second, which means Jane is moving to the right.

To determine if the collision was elastic or inelastic, you have to compare the total kinetic energy before the collision with the total kinetic energy after the collision. Elastic collisions are those in which kinetic energy is conserved.

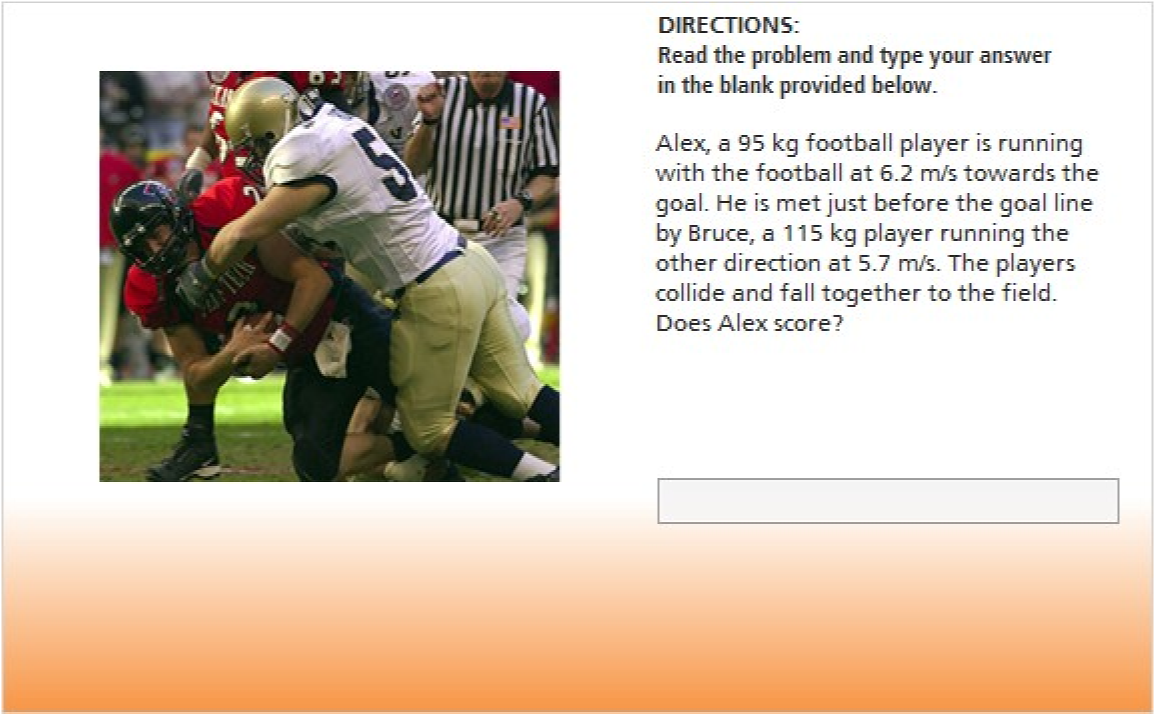
You will have one half m v squared for both Jane and Bobby before the collision and also after the collision. Substituting the masses and speeds, you find that kinetic energy before the collision was one thousand six hundred ninety five Joules, while the kinetic energy after the collision was only two hundred ninety seven Joules. This is a loss of over eighty percent of the kinetic energy, which is clearly an inelastic collision.



Summary

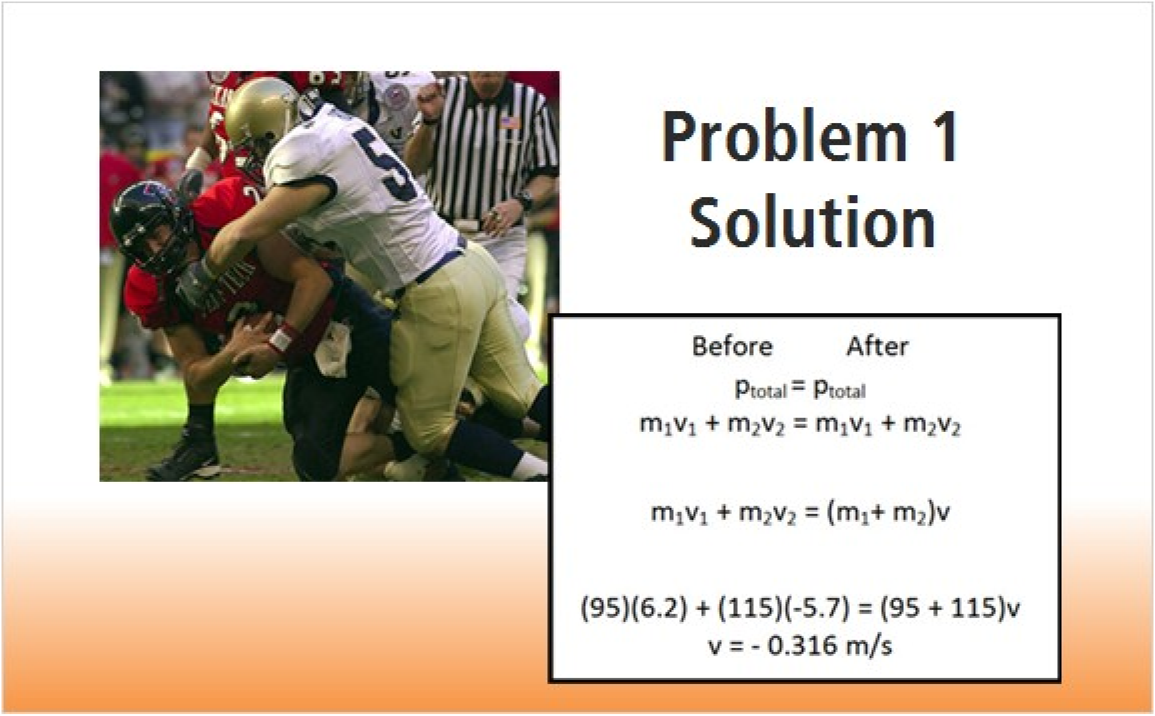
As you can see, adding up the momentum before the equation and setting it equal to the momentum after the collision provides you with a reliable way of solving momentum problems. Recognizing that when objects stick together, they move at the same speed after a collision provides you with a way to eliminate one unknown and more easily solve these problems.

Kinetic energy is conserved only in elastic collisions, but momentum is always conserved.



Problem 1:

Alex, a ninety-five kilogram football player is running with the football at six point two meters per second towards the goal. He is met just before the goal line by Bruce, a one hundred fifteen kilogram player running the other direction at five point seven meters per second. The players collide and fall together to the field. Does Alex score?



Problem 1 Solution:

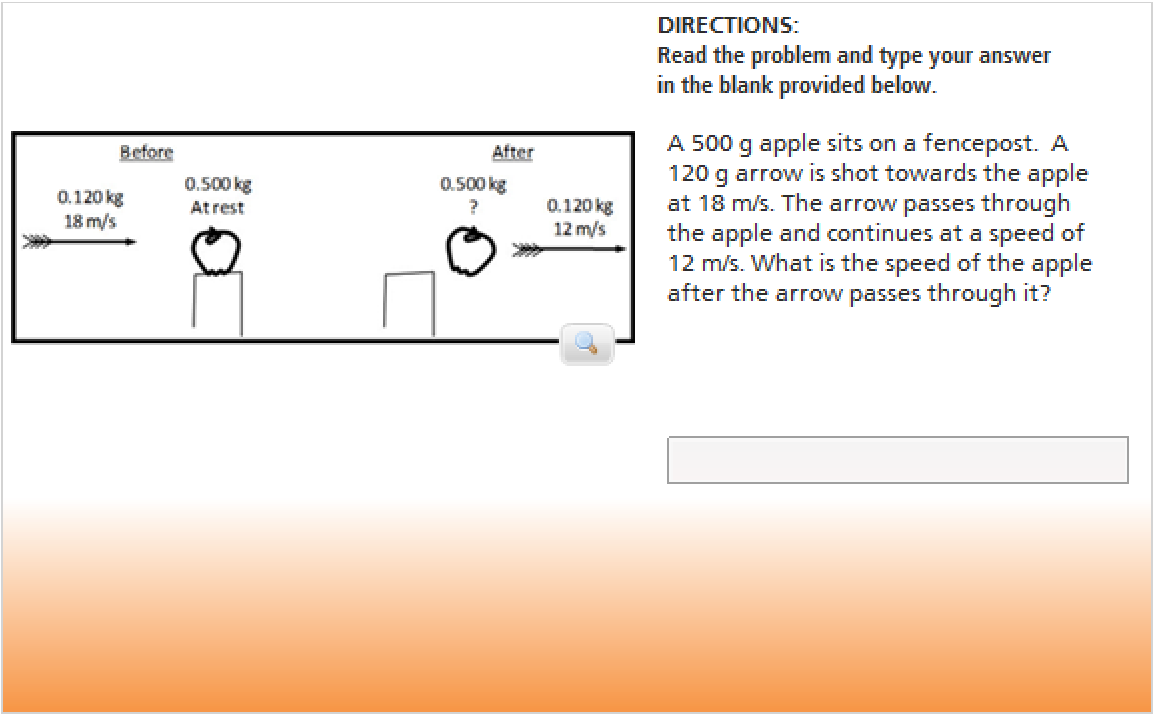
This is a conservation of momentum problem that involves a perfectly inelastic collision, one in which the objects stick together. In order to know if Alex scores, we need to know if the final velocity is in the same direction Alex was moving or if it is in the opposite direction. For this problem, we'll consider the direction Alex was initially moving to be positive, and the direction Bruce was moving to be negative.

Since momentum is conserved, we will start by setting momentum before the collision to momentum after the collision. Both objects are moving before the collision and both objects are moving after the collision, so we write m one v one plus m two v two before equals m one v one plus m two v two after.

Since Alex and Bruce move together after the collision, their velocities will be the same. We can therefore simplify the right side of the equation by combining the masses and having a single velocity.

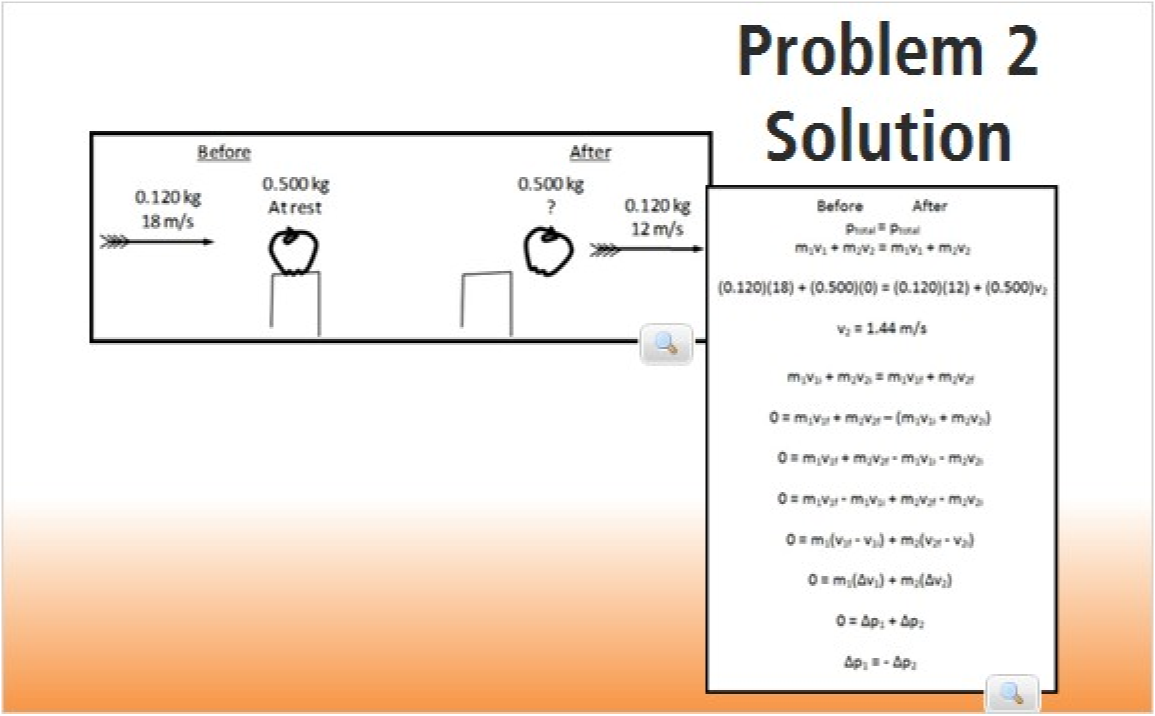
Now, we can substitute Alex's mass for m one and Bruce's mass for m two. We can also substitute both players' initial velocities for v one and v two before, keeping in mind that we set the direction Bruce was moving to be negative, so we write negative five point seven meters per second. We can now solve for v two.

We find that their combined velocity after the collision is negative zero point three one six meters per second. Since they are moving in the negative direction, this means that Alex does not score, but is instead forced backwards in the collision.



Problem 2:

A five hundred gram apple sits on a fencepost. A one hundred twenty gram arrow is shot towards the apple at eighteen meters per second. The arrow passes through the apple and continues at a speed of twelve meters per second. What is the speed of the apple after the arrow passes through it?



Problem 2 Solution:

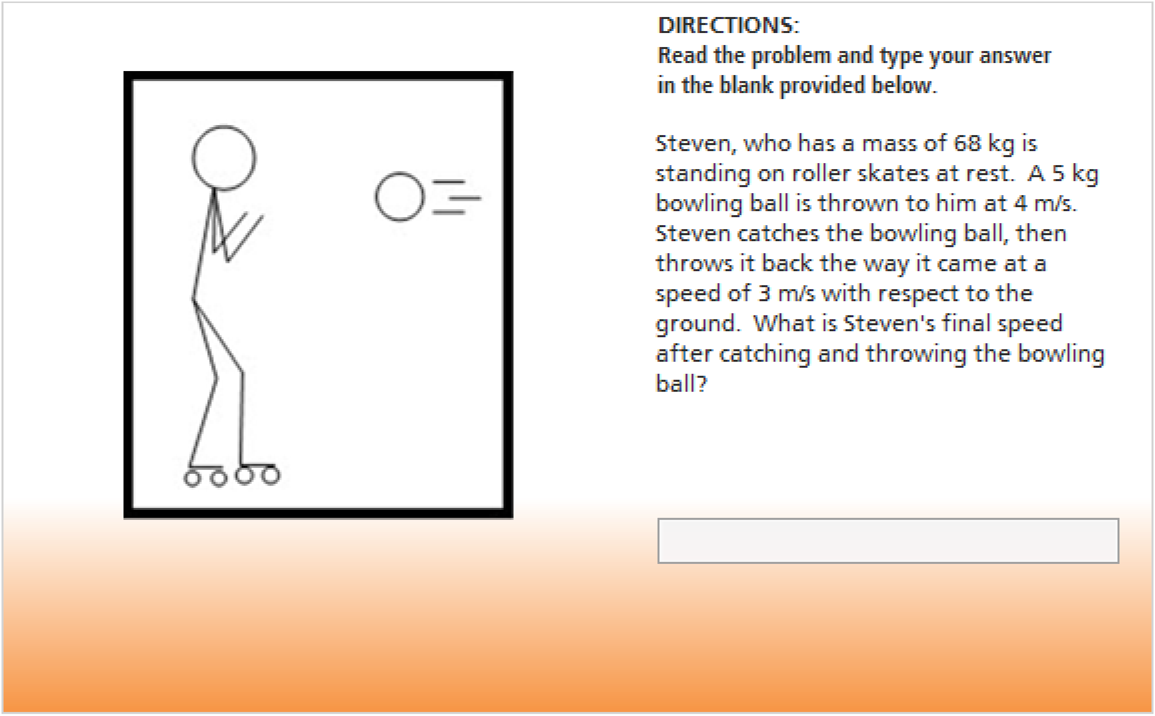
Again, we will use conservation of momentum to solve this problem. The total momentum before the interaction is the same as the total momentum after, so we start by writing m one v one plus m two v two before equals m one v one plus m two v two after. We will let the arrow be our first object and the apple be our second object.

We can substitute the mass of the arrow for m one and the mass of the apple for m two. v one before is eighteen meters per second, v two before is zero since the apple begins at rest. v one after is twelve meters per second and we're looking for v two after.

Solving for our unknown, we find that the apple has a velocity of one point four four meters per second.
Another way to think of this is that since momentum is conserved, the momentum lost by the arrow must equal the momentum gained by the apple.

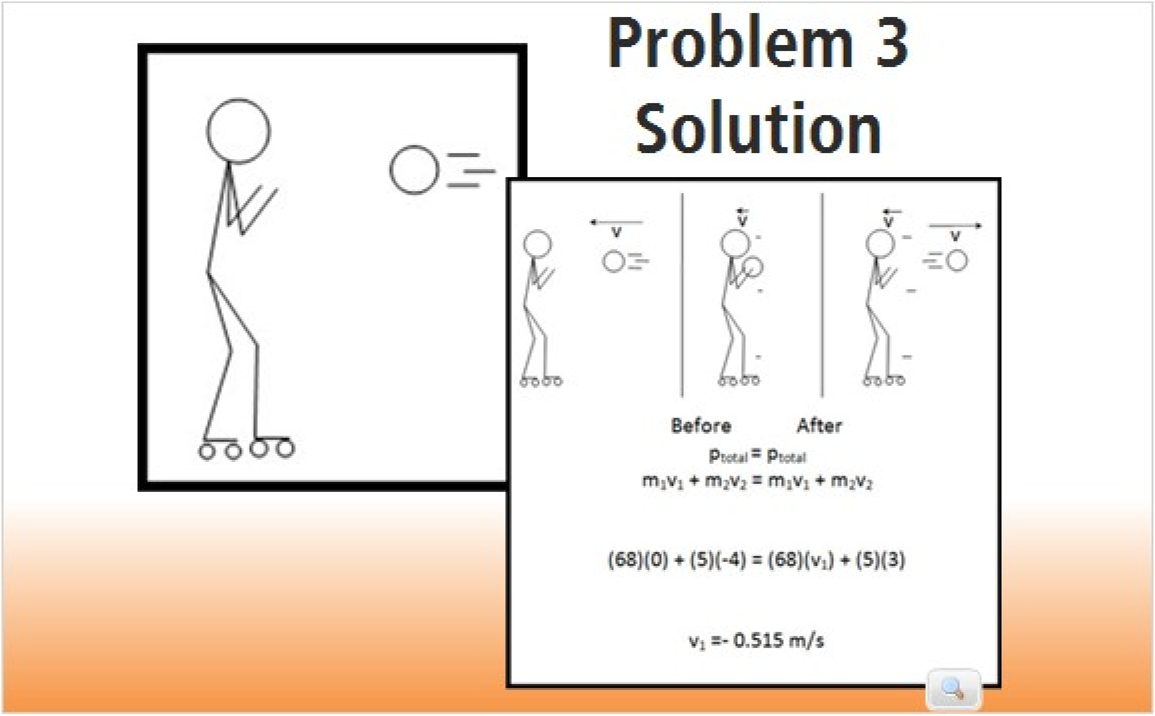
If we are careful to add additional subscripts to our velocities, with subscript i standing for initial and subscript f standing for final, we can rearrange our momentum equation to show that the change in momentum of object one plus the change in momentum of object two equals zero.

This could also be expressed as the change in momentum of the first object is equal in magnitude but opposite in direction to the change in momentum of the second object.



Problem 3:

Steven, who has a mass of sixty eight kilograms is standing on roller skates at rest. A five kilogram bowling ball is thrown to him at four meters per second. Steven catches the bowling ball, then throws it back the way it came at a speed of three meters per second with respect to the ground. What is Steven's final speed after catching and throwing the bowling ball?



Problem 3 Solution:

Again, this is a conservation of momentum problem, but this problem involves two steps. First, Steven catches the ball, which is a perfectly inelastic collision. Together, their whole mass will move to the left with the same momentum that the bowling ball had initially.

Next, we have an explosion, but both objects start in motion to the left. After the throw, the ball will move to the right, and Steven will move even quicker to the left.

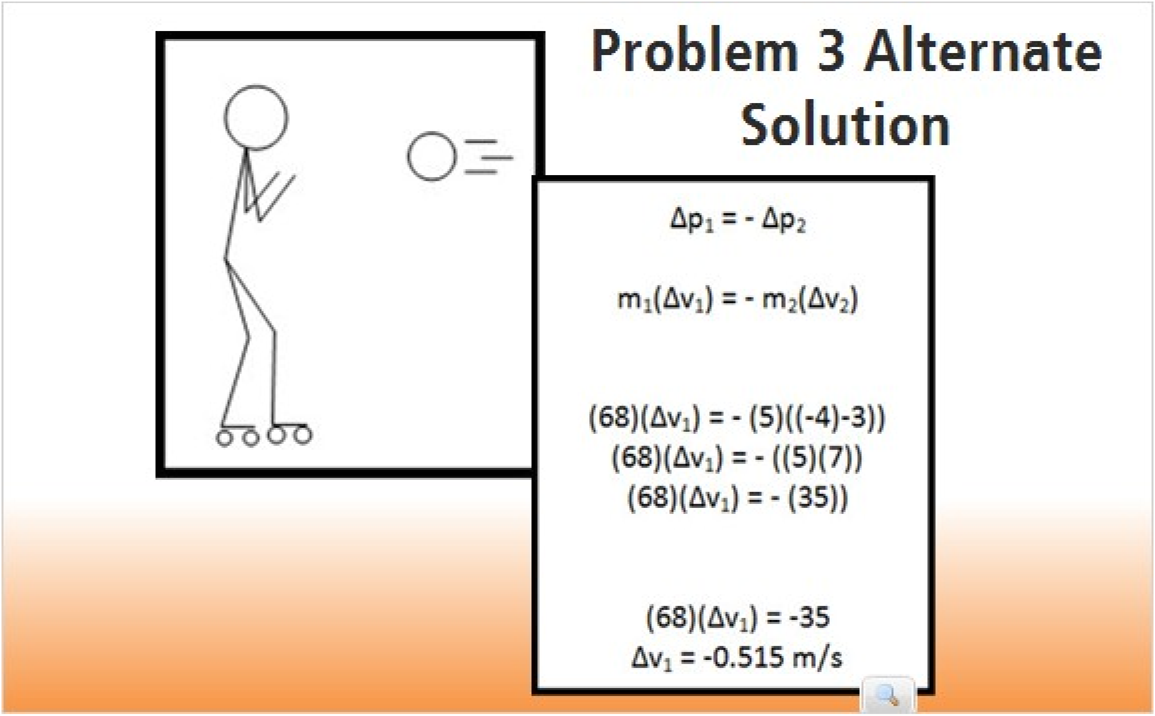
Overall, the total momentum for all three situations must be the same, and therefore the change in Steven's momentum in catching and throwing the ball must be of the same magnitude as the change in the bowling ball's momentum, but in the opposite direction.

So we will only look at the very beginning and the very end of the scenario.

Since momentum is conserved, we can use our conservation of momentum equation and write m one v one plus m two v two before equals m one v one plus m two v two after.

We will consider right positive and left negative. We'll let Steven's mass of sixty eight kilograms be m one and the ball's mass of five kilograms be m two. Steven's velocity is m one and the ball's velocity is m two. Before the catch and throw, Steven 's velocity is zero and the ball's velocity is negative four meters per second. After the catch and throw the ball's velocity is positive three meters per second and we're looking for Steven's velocity.

As we substitute all the values and solve for v one, we find that Steven's velocity is negative zero point five one five meters per second, or zero point five one five meters per second to the left.



Problem 3 Alternate Solution:

We could have also solved this problem by recognizing that Steven’s change in momentum will be equal and opposite to the ball’s change in momentum.

The ball initially had a velocity of negative four meters per second and ended with a velocity of positive three meters per second, which is a change in velocity of positive seven meters per second. The change in momentum of the ball therefore was positive thirty five kilogram meters per second.

Steven’s change in momentum is therefore negative thirty five kilogram meters per second.

We solve for Steven’s change in velocity by dividing by Steven’s mass of sixty eight kilograms and find that his change in velocity is negative zero point five on five meters per second, which is consistent with our earlier analysis.