

Teacher Toolkit - Momentum Conservation

Objectives:

1. To apply Newton's second and third law to collisions in order to compare the force and the accelerations of the two colliding objects.
2. To understand that there are four quantities that are always the same for the two colliding objects: force, time, impulse and momentum change.
3. To express an understanding of the law of momentum conservation by comparing momentum changes and total system momentum for a collision.
4. To use the law of momentum conservation to analyze a collision problem and to determine an unknown quantity.
5. To use the law of momentum conservation as a guide to proportional reasoning in order to predict the post-collision velocity of a colliding object in an inelastic collision.
6. To apply the law of momentum conservation to the analysis of explosions.

Readings: [The Physics Classroom Tutorial, Momentum and Its Conservation Chapter, Lesson 2](#)

Interactive Simulations:

1. Collision Carts <http://www.physicsclassroom.com/Physics-Interactives/Momentum-and-Collisions/Collision-Carts>
The Collision Carts Interactive provides a virtual collision track for colliding or exploding carts. The mass of the two carts and their pre-collision velocities can be varied. Inelastic and elastic collisions or explosions can be conducted. Post-collision velocities are displayed. Compatible with iPad, Chromebooks, and mobile devices.
2. PhET Collision Lab <http://phet.colorado.edu/en/simulation/collision-lab>
Use an air hockey table to investigate simple collisions in one dimension or more complex collisions. You can experiment with the number of discs, masses, and initial conditions.
3. OSP: Collision Between Two Pendulums <http://www.opensourcephysics.org/items/detail.cfm?ID=10563&Attached=1>
This Java model lets users simulate a collision between two pendulums. The activity promotes understanding of how momentum is conserved in isolated systems and the effect of mass on momentum conservation.
4. Exploding Carts <http://www.physicsclassroom.com/Physics-Interactives/Momentum-and-Collisions/Exploding-Carts>
The Exploding Carts Interactive animates several explosions between two carts on a no-friction track. Post-collisions speeds of the two carts are shown. Trials can be performed with a varying ratio of mass for the two carts. The Physics Classroom has provided a guided activity sheet.

Video and Animation:

1. Veritasium: Bullet Block Experiment <https://www.youtube.com/watch?v=vWVZ6APXM4w>
A bullet is fired into the precise center of a block of wood and its motion recorded with high-speed photography. The block is moved so the second bullet strikes the right corner of the wood block. Will the second impact cause the block to go A) Higher, B) The same height, or C) Lower than the first block.
2. Car Crash Force <http://www.watchknowlearn.org/Video.aspx?VideoID=51699&CategoryID=2511>
This 6-minute Mythbusters video summarizes the "Car Crash Force", with the best of the slo-mo video. We watch two cars of identical design and mass being crashed into a wall -- one at 50 mph and one at 100 mph. The damage to the faster-moving car is a great way to envision why the kinetic energy equation works for car crash.
3. Crash Force Aftershow <http://www.discovery.com/tv-shows/mythbusters/videos/crash-force-aftershow/>
Without this 4-minute "aftershow" explanation, the Mythbusters Car Crash Force could be shoved in the "interesting trivia" file. This video connects the crash to the physics.
4. Physlet Physics: Momentum Problems http://www.compadre.org/Physlets/mechanics/prob8_1.cfm
If you use clickers or student response systems, this set of 14 Physlet problems would be an ideal addition to your toolkit. The problems are animation-based, with multiple choice answers provided.
5. Physlet Physics: Understanding Conservation Laws http://www.compadre.org/Physlets/mechanics/ex8_1.cfm
This mini-collection from Physlet Physics features 7 Java-based animations that delve into conservation of momentum in both elastic and inelastic collisions.
6. Richard Hammond's Blast Wave in Slow Motion <https://www.youtube.com/watch?v=TjC4SvZIARY>
FANTASTIC videography showcases two explosions to clearly depict the propagation of a blast wave that accompanies an explosion. The video clip is a great class warm-up.
7. Circus Physics: Linear Momentum <http://www.pbs.org/opb/circus/classroom/circus-physics/linear-momentum/>
This video-based resource explores linear momentum through a platform system consisting of two trapeze artists. The video is crafted to help students understand how momentum is conserved.

Labs and Investigations:<http://www.physicsclassroom.com/lab/index.html#mom>

1. The Physics Classroom, The Laboratory, Before and After
2. The Physics Classroom, The Laboratory, Action-Reaction
3. The Physics Classroom, The Laboratory, Sand Balloon
4. The Physics Classroom, The Laboratory, Inelastic Collision Analysis
5. The Physics Classroom, The Laboratory, Elastic Collision Analysis
6. The Physics Classroom, The Laboratory, What's Cooking?

Interactive HW Problems**(See Complete Toolkit at TPC's Teacher Toolkit website for full description.)**

1. Spring-Loaded Collision http://per.physics.illinois.edu/per/IE/ie.pl?phys111/ie/08/IE_spring_loaded_collision
2. Ballistic Pendulum <http://per.physics.illinois.edu/per/IE/ie.pl?phys101/ie/07/bpendulum>

Minds On Physics Internet Modules:<http://www.physicsclassroom.com/mop>

The Minds On Physics Internet Modules are a collection of interactive questioning modules that target a student's conceptual understanding. Includes detailed help that addresses the various components of every question.

Momentum and Collisions Module:

Ass't MC5 - Momentum Conservation

Ass't MC7 - Momentum Conservation

Ass't MC9 - Problem-Solving - Elastic Collisions

Ass't MC4 - Force, Impulse and Momentum Change

Ass't MC6 - Explosion-Like Impulses

Ass't MC8 - Problem-Solving - Inelastic Collisions

Ass't MC10 - Momentum and Proportional Reasoning

Concept Building Exercises:<http://www.physicsclassroom.com/curriculum/momentum>

The Curriculum Corner, Momentum and Collisions

Action-Reaction and Momentum Conservation

Momentum Problem-Solving

Collision Analysis

Momentum Conservation as a Guide to Thinking

Problem-Solving Exercises:<http://www.physicsclassroom.com/calcpad/momentum/problems>

1. The Calculator Pad, Momentum and Collisions, Problems #12 - #30

Science Reasoning Activities:<http://www.physicsclassroom.com/reasoning/momentum>

1. The Science Reasoning Center – Momentum and Collisions - Collisions

Common Misconceptions**(See Complete Toolkit at TPC's Teacher Toolkit website for full description.)**

1. Velocity is Conserved

Extension Activities**(See Complete Toolkit at TPC's Teacher Toolkit website for full description.)**

1. OSP: Ejs Hard Disk Collision Model <http://www.opensourcephysics.org/items/detail.cfm?ID=7572>
2. OSP: Two Particle Elastic Collision Model <http://www.thephysicsfront.org/items/detail.cfm?ID=8373>

Standards:**Next Generation Science Standards****(See Complete Toolkit for full description.)****Performance Expectations – Motion and Stability: Forces and Interactions****HS-PS2-3** Apply scientific and engineering ideas to design, evaluate, and refine a device**HS-PS2-2** Use mathematical representations to support the claim that the total momentum of a system**Disciplinary Core Ideas – Grades 9-12 Forces and Motion HS-PS2.A.ii****Crosscutting Concepts****Systems and System Models – Crosscutting Concept #4****Stability and Change – Crosscutting Concept #7****Science and Engineering Practices****Practice #1: Analyzing and Interpreting Data****Practice #2: Developing and Using Models****Practice #3: Planning and Carrying Out Investigations****Practice #6: Obtaining, Evaluating, and Communicating Information****Practice #8: Using Mathematics and Computational Thinking**