Teacher Toolkit - Impulse-Momentum Change Theorem

Objectives:

1. To define momentum, identify the equation relating momentum to mass and velocity, identify the units of momentum, and identify the direction of the momentum vector.
2. To define impulse and describe its affect upon an object's momentum.
3. To use the impulse-momentum change equation to analyze a collision in order to determine an unknown quantity in a collision problem.
4. To use the impulse-momentum change equation as a guide to thinking about how a change in one quantity affects another quantity.
5. To explain a variety of applications of the impulse-momentum change equation that pertain to safety.

Readings: The Physics Classroom Tutorial, Momentum and its Conservation Chapter, Lesson 1

Reference Guide on Teaching Momentum http://www.thephysicsfront.org/items/detail.cfm?ID=3356
From AAPT's Physics Teacher Resource Agents, the opening page of this manual contains its central message: "Impulse should be uttered in the same breath with momentum". It's intended to support high school teachers in teaching about momentum topics

Interactive Simulations:

1. PhET Collision Lab http://phet.colorado.edu/en/simulation/collision-lab
Investigate simple collisions in one dimension or more complex collisions. You can experiment with the number of discs, masses, and initial conditions. The simpler 1D simulation allows beginners to explore what "elasticity" means, while the 2D sim lets them apply the Law of Conservation of Momentum to solve problems.
2. Egg Drop Interactivehttp://www.physicsclassroom.com/Physics-Interactives/Momentum-and-Collisions/Egg-Drop
The Egg Drop Interactive provides a virtual egg drop activity. Learners can vary the mass of the egg that is dropped, the height from which it is dropped, and the surface onto which it is dropped. The egg drop is simulated and the result is displayed. The impulse-momentum change theorem is used to show how the force is calculated from the egg drop parameters that are selected. The Interactive provides an eggcellent demonstration of how alterations in one variable affect another variable. Accompanied by an exercise page.

Video and Animation:

1. Physlet Physics: Momentum Illustrations http://www.compadre.org/Physlets/mechanics/intro8.cfm
This is a set of 8 focused Java animations that would be ideal warm-ups for introducing momentum and impulse. Each one is accompanied by an explanation of the physics and mathematical examples.
2. Physics of Superheroes: Death of Gwen Stacy https://www.youtube.com/watch?v=kuVpwjYgvgg
This 5-minute video features University of Minnesota physics professor Jim Kakalios proving how Spiderman's girlfriend, Gwen Stacy, died. Dr. Kakalios uses a combination of humor and math to show how the scenario can be calculated using the equation $p = m \bullet v$.
3. The Science of Speed: Momentum and Time http://www.nsf.gov/news/special_reports/sos/momentumtime.jsp
This 4.5 minute video sponsored by the National Science Foundation delves into the science behind the SAFER Barrier walls on NASCAR tracks. The video also explores how seat belts and the HANS (Head-and-Neck Safety) device help spread out the force of impact and save lives.
4. Smarter Every Day: Underwater Explosions https://www.youtube.com/watch?v=Aan-kc-9E3A
Detonating a small explosion in water and recording the event with a Phantom high speed camera offers a unique way to observe impulse and momentum in a fluid. Author/host is mechanical engineer Destin Sandlin, who provides not just breathtaking video, but also backs it up with diagrams and relevant equations.
5. LivePhoto Physics http://livephoto.rit.edu/LPVideos/carts_CoM/
This resource consists of six short Quicktime videos of a cart moving from left to right colliding with a stationary cart. Mass is varied in each video so that three elastic collisions and three inelastic collisions are depicted. The videos were developed for computer analysis in introductory physics classrooms.

Labs and Investigations http://www.physicsclassroom.com/lab#mom

1. The Physics Classroom, The Laboratory, Being Impulsive About Momentum
2. The Physics Classroom, The Laboratory, Balloon Toss
3. The Physics Classroom, The Laboratory, Rebounding versus Sticking

Classroom Demonstration:

1. Flinn Scientific: Bouncing with Momentum http://www.flinnsci.com/media/1167851/ps10871.pdf
   This activity can be done as a teacher demo or as a cooperative learning exercise. Students will place a ping-pong ball on top of a mini-basketball, then simultaneously drop both balls. The mini-basketball, having more momentum, will hit the floor and rebound upwards…..colliding into the ping-pong ball. When the balls collide, the momentum of the basketball is imparted to the ping-pong ball. The resource includes sample data tables.

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. Each question is accompanied by detailed help.

1. Momentum and Collisions module, Ass't MC1 - Momentum
2. Momentum and Collisions module, Ass't MC2 - Impulse and Momentum Change
3. Momentum and Collisions module, Ass't MC3 - Impulse-Momentum Change Variables

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

1. The Curriculum Corner, Momentum and Collisions, Momentum, Impulse and Momentum Change
2. The Curriculum Corner, Momentum and Collisions, Controlling a Collision
3. The Curriculum Corner, Momentum and Collisions, Simple Computations with Impulse = Momentum Change

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

1. The Calculator Pad, Momentum and Collisions, Problems #1 - #11

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

1. Marshmallow Launcher
2. Air bag Inflation and Passenger Safety

Real Life Connections:

1. Understanding Car Crashes – It's Basic Physics https://www.youtube.com/watch?v=yUpiV2I_IRI
   This 22-minute video goes behind the scenes at the Insurance Institute for Highway Safety to give students an up-close look at the physics of car crashes. For a complete Teacher's Guide, click here: Understanding Car Crashes - Teachers Guide
2. Problem-Based Learning: Collision Investigation
   http://pbl.ccdmd.qc.ca/resultat.php?action=clicFiche&he=1050&afficheRecherche=99&IDFiche=150&endroitRetour=99&lesMotsCles=collision
   This PBL (Problem-Based Learning) activity involves a crash where a small car is struck broadside by a vehicle of more than double its mass. Students must determine whether either driver engaged in reckless driving.

Common Misconceptions **(See the complete toolkit at TPC's Teacher Toolkit website for details.)**

1. Terminology - Force, Impulse, Momentum, Momentum Change, Velocity Change
2. Rebounding Collisions are Safer than Inelastic Collisions

Standards:

A. Next Generation Science Standards (NGSS) – Grades 9-12

Performance Expectations – Motion and Stability: Forces and Interactions HS-PS2-2 and HS-PS2-3
Disciplinary Core Ideas – Grades 9-12 Forces and Motion HS-PS2.A.ii
Systems and System Models – Crosscutting Concept #4
Stability and Change – Crosscutting Concept #7
Science and Engineering Practices: #1, #2, #3, #6, and #8