Teacher Toolkit - Newton's Third Law

Objectives:

1. To state Newton's third law of motion and relate its meaning to the concept of a force as a mutual interaction between objects.
2. To relate Newton's third law of motion to the definition of a force.
3. To use Newton's third law of motion to make a comparison of the magnitude of the individual forces in any interaction.
4. To identify the action-reaction force pairs for any physical interaction.

Readings: The Physics Classroom Tutorial, Newton's Laws of Motion Chapter, Lesson 4

Video and Animation:

1. Veritasium: Jetpack Rocket Science https://www.youtube.com/watch?v=Hx9TwM4Pmhc
   This short video by physicist Derek Muller explores the physics behind jetpack rockets. Water is pumped out of the lake by the jetski at about 60 liters/second, then fired out the nozzles at 15 m/s, creating 1800N of force. That's roughly equivalent to 150 fire extinguishers.
2. SERC: Water Jetpack https://serc.carleton.edu/sp/library/dmvideos/videos/water_jetpack.html
   This short clip, appropriate for video analysis, shows a person on a water-powered jetpack. It was prepared by veteran high school teacher Peter Bohacek and is part of the SERC Direct Measurement Video Library. Direct measurement videos are short, very high-quality clips of real events that allow students to integrate video analysis tools to explore physical phenomena in an introductory mechanics course.
3. McMillan Space Centre: Newton's Third Law of Motion https://www.youtube.com/watch?v=_sr3hBxu614
   Using a 2-liter plastic bottle and a bit of rocket propellant, Cam Cronin of Canada's McMillan Space Centre illustrates action/reaction in a controlled explosive "launch".
4. Physlet Physics: Newton's Third Law http://www.compadre.org/Physlets/mechanics/illustration4_6.cfm
   This animation gives students the challenge to match the motion of a particular physical situation involving a two-body system. Given a net force of 12N, students must determine the correct ratio of contact forces between the larger and smaller block to make the animation run as it should.
5. Veritasium: Best Film on Newton's Third Law – Ever https://www.youtube.com/watch?v=8bTdMmNZm2M
   Derek Muller interviews a collection of people regarding Newton's Third Law of Motion. All incorrectly interpreted its meaning for gravitational attraction between the Earth and moon, insisting that Earth exerts a greater magnitude of force on the moon than moon exerts back on Earth. Dr. Muller explains why they were confused as he explores the role played by inertia.
6 Direct Measurement Video: Cart Push-Off https://serc.carleton.edu/sp/library/dmvideos/videos/cart_push.html
   This set of 3 short video clips, appropriate for video analysis, shows students on low friction carts. Initially stationary, they push off each other, sending each cart moving in opposite directions. By measuring the speed of each cart after push-off, learners can calculate the momentum of each cart and system momentum.
7. Physics By Discovery: Interaction Force Pairs https://www.youtube.com/watch?v=wHgRIQT4b98
   This video does a great job explaining the difference between interaction force pairs and force representations in a free-body diagram. The explanation is especially strong in its treatment of the normal force, an area of documented misconception among learners.
8. Rutgers University Learning Cycle: Newton's Third Law
   Forces Approach http://paer.rutgers.edu/pt3/experimentindex.php?topicid=3&cycleid=3
   Eugenia Etkina of Rutgers University Department of Physics authored these two learning cycles on Newton's Third Law. Each contains a set of 30-second videos that show a physical phenomenon. After watching a video, students undergo a "qualitative cycle" and then a "quantitative cycle" are used to analyze the video.

Labs and Investigations:

1. Modeling Program: Inertia and Newton's Third Law http://modeling.asu.edu/Modeling-pub/Mechanics_curriculum/4-FP-inertia/01_U4%20Teachernotes.pdf
   This teacher's guide from Arizona State University explains how to introduce the modeling cycle to teach about Newton's First and Third Laws. This lesson module seeks to help students transition from a descriptive model using kinematics to a causal model using dynamical laws of motion. *Contains procedures for 2 classroom demos, one lab, and 4 class investigations.*

2. Forces and Newton's Laws https://www.physics.upenn.edu/uglabs/experiments/newtons_laws/Newtons_Laws.pdf
   If your lab is equipped with dynamic carts, a force sensor, dynamics sensor, and Logger Pro, this lab will provide a means for students to correctly apply Newton's Laws. It focuses particularly on the Third Law, which the author believes is "the most non-intuitive of all". It takes learners step-by-step through each phase of three investigations, including pre-lab conceptual exercises and how to calculate uncertainty for large data sets.

Demonstration Ideas:

1. ScienceFix: Newton's Third Law – Sled Launch https://www.youtube.com/watch?v=D4j5bcaV2Ws
   Simple, but effective demo to illustrate action/reaction in a tabletop sled system. Microbeads are used to create a low-friction surface. When a rubber band under tension is cut, the sled is launched. The video reveals that the sled and the launch mechanism exert equal but opposite force on the other.
2. The Physics Classroom's Third Law on YouTube http://youtu.be/1-Es7v8J06o
   This simple slow-mo video demonstration from The Physics Classroom displays two carts on a track, each equipped with force probes connected by a spring. The carts are pushed away from each other and the spring begins to exert forces on the carts. A plot of force versus time is displayed in real time, showing that the forces are equal in magnitude and opposite in direction.

Minds On Physics Internet Modules:

The Minds On Physics Internet Modules are a collection of interactive questioning modules that target a student's conceptual understanding. Accompanied by detailed, question-specific help.

1. Newton's Laws Module, Assignmentt NL12 - Newton's Third Law
   Link: http://www.physicsclassroom.com/mop

Concept Building Exercises:

1. The Curriculum Corner, Newton's Laws of Motion, Newton's Third Law
   Link: http://www.physicsclassroom.com/curriculum/newtlaws

Real Life Connections:

1. Science of NFL Football: Newton's Third Law
   http://science360.gov/obj/video/d0e16d27-05d4-4511-9394-2758aa066981/science-nfl-football-newtons-third-law-motion
   This video from NBC Learn breaks down Newton's Third Law to discuss action/reaction between football players who collide on the field. Professors Tony Schmitz of the University of Florida and Jim Gates of the University of Maryland take it a step further to explain the role of conservation of momentum.

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

1. First Action, Then Reaction
2. The Force Values are Different for Different Objects
3. Action-Reaction Forces Balance Each Other

Standards:

A. Next Generation Science Standards (NGSS) **(See the complete toolkit for details.)**

Performance Expectations – Motion and Stability (Middle School: MS-PS2-1)
Disciplinary Core Ideas – Motion and Stability (Middle School: MS-PS2.A.i)
NGSS Science and Engineering Practices: Practice #2, #3, and #4
NGSS Nature of Science Standards