

## Teacher Toolkit

### Topic:

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

<http://www.physicsclassroom.com/class/newtlaws/Lesson-4/Newton-s-Third-Law>

### Video and Animation:

1. Veritasium: Jetpack Rocket Science

9-minute Video

<https://www.youtube.com/watch?v=Hx9TwM4Pmhc>

This short video by physicist Derek Muller explores the physics behind jetpack rockets. It works on the same principle as a spacecraft being launched, but you don't use rocket propellant to provide the thrust. Instead, 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. *We like this resource because it's a great way to visualize Newton's Third Law. It's simpler than a jet engine, but clearly shows the action/reaction resulting from the high-speed expulsion of water.*



2. SERC Pedagogy in Action: Water Jetpack

20-second Video Clip

[https://serc.carleton.edu/sp/library/dmvideos/videos/water\\_jetpack.html](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. The video can be viewed in



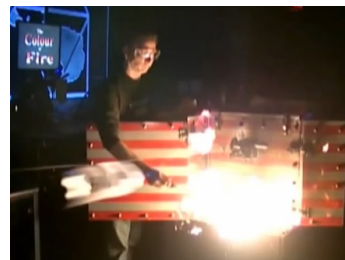
Quicktime for frame-by-frame viewing, or on YouTube. *Great companion to the Veritasium video directly above.*

3. McMillan Space Centre: Newton's Third Law of Motion

3-minute Video

[https://www.youtube.com/watch?v=\\_sr3hBxu614](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". The relevance of Newton's Third Law is explained throughout the video.

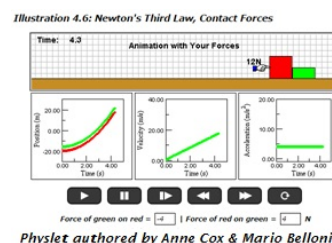


4. Physlet Physics: Newton's Third Law – Contact Forces

Animated Illustration

[http://www.compadre.org/Physlets/mechanics/illustration4\\_6.cfm](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. (*Hint: Even if students have to do some trial and error, they should figure out that the force on the smaller green block must be equal, but opposite to, the force on the larger red block. This bears out Newton's Third Law, and gives kids a chance to model the situation in a unique way.*)



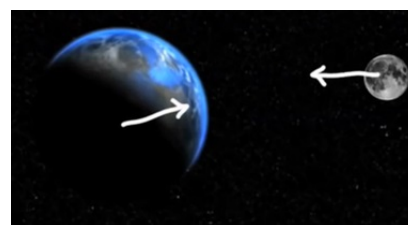
Physlet authored by Anne Cox & Mario Belloni

5. Veritasium: Best Film on Newton's Third Law – Ever

5-minute Video

<https://www.youtube.com/watch?v=8bTdMmNZm2M>

Here's physicist Derek Muller again with a fascinating look at misconceptions about the Third Law. All the people he interviewed could correctly state Newton's Third Law of Motion. But they 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 SERC Direct Measurement Video: Cart Push-Off

Set of Video Clips

[https://serc.carleton.edu/sp/library/dmvideos/videos/cart\\_push.html](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. The three scenarios presented are: 1) Two students of similar mass, 2) Two students on one cart, one student on the other cart, and 3) Two students of different masses.

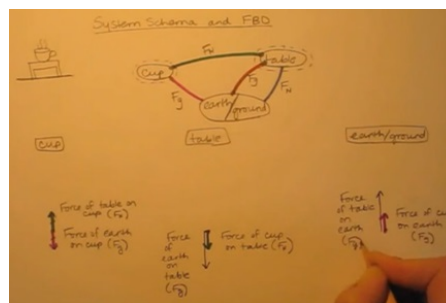


## 7. Physics By Discovery: Interaction Force Pairs Example

8-minute Video

<https://www.youtube.com/watch?v=wHgRIQT4b98>

This video by high school teacher Karen Hunter does a great job of 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. We would recommend this video for your visual learners and for students who are struggling with the content.



## 8. Rutgers University Learning Cycle: Newton's Third Law

Learning Cycle

*Newton's Third Law: Forces Approach*

<http://paer.rutgers.edu/pt3/experimentindex.php?topicid=3&cycleid=3>

*Newton's Third Law: Momentum Approach*

<http://paer.rutgers.edu/pt3/experimentindex.php?topicid=3&cycleid=4>

One of the most respected names in physics education research, Eugenia Etkina of the 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" to consider whether the video supports or refutes a law or theory of physics. Next comes the "quantitative cycle" where students use mathematics to find patterns, predict results, and/or propose alternative models.

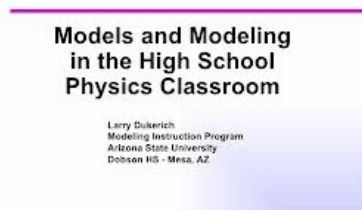


## Labs and Investigations:

1. Modeling Instruction Program: Inertia and Newton's Third Law Instructional Unit

[http://modeling.asu.edu/Modeling-pub/Mechanics\\_curriculum/4-FP-inertia/01\\_U4%20Teachernotes.pdf](http://modeling.asu.edu/Modeling-pub/Mechanics_curriculum/4-FP-inertia/01_U4%20Teachernotes.pdf)

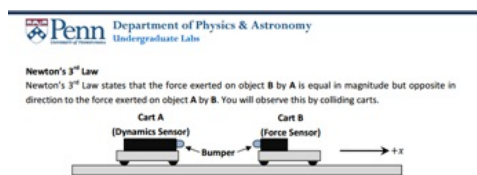
This teacher's guide from Arizona State University explains how to introduce the modeling cycle to teach about Newton's First and Third Laws. To quote the author, "The great majority of university students can state Newton's Laws, but careful evaluation reveals that even at the end of the course they cannot consistently apply the laws correctly." One particularly stubborn error in reasoning is that in interactions between two objects, the larger or more active object exerts the greater force. 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. University of Pennsylvania: Forces and Newton's Laws Lab Experiment

[https://www.physics.upenn.edu/uglabs/experiments/newtons\\_laws/Newtons\\_Laws.pdf](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. The first lab explores a cart/pulley/hanging mass system; the second involves a collision in one dimension between a pair of carts for observation of equal-but-opposite forces; the third lab involves the collision of a cart with an aluminum foil crumple zone.



## Demonstration Ideas:

1. ScienceFix: Newton's Third Law – Sled Launch 1-minute Video Demonstration

<https://www.youtube.com/watch?v=D4j5bcaV2Ws>

Simple, but effective demo to illustrate action/reaction in a tabletop sled system. The author uses microbeads to create a very low-friction surface to mimic an idealized system. When a rubber band under tension is cut, the sled is launched. Both the sled and the launch mechanism exert equal but opposite force on the other, which is well-illustrated in the video.

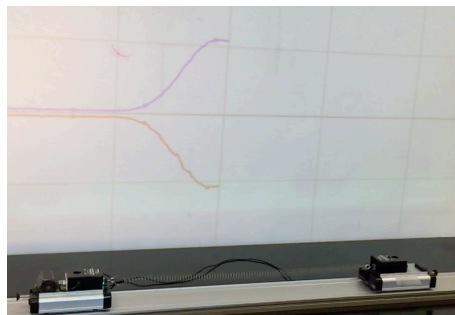


## 2. The Physics Classroom's Third Law on YouTube

10-second Demonstration

<http://youtu.be/1-Es7v8J06o>

This simple slow-mo video demonstration from The Physics Classroom displays two carts on a track. The carts are equipped with force probes and a spring connects the two force probes. The force probe on the left cart is measuring the force of right cart pulling on it (though the force is actually *transmitted* to the cart by the spring). The force probe on the right cart is measuring the force of the left cart pulling upon it. The video displays the readings from the force probes in real time. One quickly realizes from the graphical display that the forces on the two carts are equal in magnitude and opposite in direction. With similar equipment, any teacher could easily repeat the demo live in front of their students.



### 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. Each question is accompanied by detailed help that addresses the various components of the question.

#### 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

4-minute Video

<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

### 1. First Action, Then Reaction

Newton's third law essentially defines a force as a push or pull that an object experiences as a result of its interaction with another objects. That is, forces are the result of mutual and simultaneous interactions between two objects. The common misconception is to conceive of Newton's third law as though one object pushes upon another object, and as a result, some short time later, the other object pushes back. The phrase *action and reaction force pairs* might best be replaced by the phrase *interaction force pairs*.

### 2. The Force Values are Different for Different Objects

The forces that act between objects during an interaction are equal in magnitude on the two interacting objects. There are a variety of misconceptions associated with the magnitude of the two forces. One misconception is that the force is greatest on the least massive object. A second misconception is that the force is greater on any object that begins at rest and is hit by a moving object. The law is clear: the magnitude of the forces are equal. While the accelerations that result from the forces may be different, the force values are the same.

### 3. Action-Reaction Forces Balance Each Other

The third law states that the individual forces experienced by interacting objects is equal in magnitude and opposite in direction. For some students, this language of equal and opposite leaves the impression that they will balance each other out. But the forces of the interaction act upon different objects. When we consider whether or not two forces will balance one another, we consider the forces that act upon a single object. Thus, the interaction forces could never balance one another since they act on opposing objects.

## Standards:

### A. Next Generation Science Standards (NGSS)

#### Performance Expectations – Motion and Stability

- **Middle School: MS-PS2-1** – Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.

#### Disciplinary Core Ideas – Motion and Stability

- **Middle School: MS-PS2.A.i** 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).

### NGSS Science and Engineering Practices

#### Practice #4: Analyzing and Interpreting Data

- **Grades 9-12:** Analyze data using computational models in order to make valid and reliable claims.

#### Practice # 2: Developing and Using Models

- **Grades 9-12:** Use a model to predict the relationships between systems or between components of a system.



- **Grades 9-12:** Use a model based on evidence to illustrate the relationships between systems or between components of a system.

### **Practice #3: Planning and Carrying Out Investigations**

- **Grades 9-12:** Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements.

### **NGSS Nature of Science Standards**

- Science Laws and Theories Explain Natural Phenomena
  - **Grades 6-8:** Science laws are regularities or mathematical descriptions of natural phenomena.
  - **Grades 9-12:** Science laws are statements or descriptions of the relationships among observable phenomena.