Teacher Toolkit - Newton's Second Law

Objectives:

1. To identify the type and relative magnitude of the individual forces that act upon an object and to use such information to construct free-body diagrams for a physical situation.
2. To understand the meaning of net force and to use such an understanding to relate the values of individual forces to the value of the net force.
3. To distinguish between the concepts of mass and weight and perform calculations involving mass and weight.
4. To state Newton's second law of motion, to express in equation form, and to use it to solve for acceleration, mass, or net force if knowledge of two of these three variables are known.
5. To use Newton's second law equation as a guide to thinking about the relationship between F, m, and a.
6. To use free-body diagrams and the Newton's second law equation to determine the acceleration of an object.
7. To use free-body diagrams and the Newton's second law equation to determine the value of an individual force that acts upon an object.

Readings: The Physics Classroom Tutorial, Newton's Laws Chapter, Lesson 2
The Physics Classroom Tutorial, Newton's Laws Chapter, Lesson 3

Physics Education Research

1. **Free Body Diagrams** http://journals.aps.org/prstper/abstract/10.1103/PhysRevSTPER.5.010108
   Here's a free research article (courtesy of the American Physical Society) that delves into the importance of free-body diagrams in physics instruction.

Interactive Simulations:

1. PhInT: Free Body Diagrams http://www.physicsclassroom.com/Physics-Interactives/Newtons-Laws/Free-Body-Diagrams
   Students are presented with 12 physical situations for which they must construct free-body diagrams. Students select buttons to create the diagram and receive immediate feedback. This HTML5-friendly interactive has a built-in score-keeping, making it a perfect tool in a 1:1 classroom.
2. PhInt: Force http://www.physicsclassroom.com/Physics-Interactives/Newtons-Laws/Force
   This interactive simulation allows students to probe the relationship between net force, mass and acceleration. A force is applied to push a box across a horizontal surface. The mass of the box, the magnitude of the force, and the amount of friction can be adjusted. This HTML5-friendly Interactive is accompanied by two different activities designed for different student abilities and different purposes.
3. PhInt: Rocket Sledder http://www.physicsclassroom.com/Physics-Interactives/Newtons-Laws/Rocket-Sledder
   This HTML5 simulation allows users to explore the effect of balanced and unbalanced forces upon an object's motion. As a rocket-propelled sled moves across a snowy surface, the speedometer changes to demonstrate the effect of an unbalanced force upon the speed. Force diagrams are depicted during the motion. The amount of friction and air resistance and the amount of mass and thrust can all be altered.
4. PhET: Forces and Motion http://phet.colorado.edu/en/simulation/forces-and-motion
   This interactive simulation provides four components for exploring balanced and unbalanced forces. Students can choose from among 5 objects of different masses, set the surface with or without friction, then "push" the object along a straight line. The simulation displays force vectors and free body diagrams to match the motion.
5. Concord Consortium: Spring and Mass Model http://concord.org/stem-resources/spring-and-mass
   Explore forces that affect a spring's motion in this simple model. Students can adjust spring constant, starting position, mass of the weight, and damping.

Video and Animation:

1. Friction and the Normal Force https:// www.youtube.com/watch?v=rzEhNCbu1_g
   This 15-minute video investigates two of the most common contact forces: friction and the normal force. It provides multiple real-world examples, gives explicit guidance in how to identify and label both forces in free-body diagrams, and demonstrates how to apply these concepts to solve problems.
2. Concord Consortium: VISUAL Project http://concord.org/projects/visual#about
   This new set of computer-based visualizations explores what happens at the molecular level when force is applied to various types of materials -- ceramics, metals, plastic, and rubber tires. The authors' purpose is to encourage learners to interpret conceptually how force interactions at the nanoscale affect an object's properties at the macroscale.
3. Concord Consortium: Tire Forces http://concord.org/stem-resources/tire-forces

We like this simple animation because it underscores the importance of molecular structure in how a material will respond to an applied force. In this case, the material is tire rubber -- a polymer composed of long molecular chains. It also meets specific Next Generation Science Standards-Structure of Matter.

4. The Physics of Sailing http://www.pbslearningmedia.org/resource/kqed09.sci.phys.maf.kqedsailing/the-physics-of-sailing/
   This high-definition 10-minute video from QUEST explains how modern sailboats move forward by generating lift. The video explores the aerodynamic forces generated by two parts of the sailboat: the sails and the keel.

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

The Physics Classroom, The Laboratory, Newton's Laws of Motion

1. Wait! Hmmm. Gee.
2. F-m-a Lab
3. Coffee Filter Skydiver Lab
4. Friction
5. Mu Shoe Phyzx
6. Normal Force-o-Meter

Real Life Connections: **See the complete toolkit at TPC's Teacher Toolkit website for details.**

1. Materials Lab (PBS) http://www.pbslearningmedia.org/resource/phy03.sci.phys.mfw.bbmatrls/materials-lab/
2. The Physics of Stone Arches http://www.pbslearningmedia.org/resource/nv37.sci.engin.design.arches/physics-of-arches/

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 that addresses the various components of the question.

Newton's Laws, Assignments NL4 through NL11 - Types of Forces

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

The Curriculum Corner, Newton's Laws

1. Recognizing Forces
2. Mass and Weight
3. Newton's Second Law of Motion
4. Net Force and Acceleration
5. Free Body Diagrams
6. Newton's Second Law
7. Drawing Free Body Diagrams
8. Friction
9. Air Resistance and Terminal Velocity
10. The Elephant and the Feather
11. Skydiving
12. Newton's 2nd Law Problems

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

1. The Calculator Pad, Newton's Laws of Motion, Problems #1 - #30

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

Science Reasoning Center, Newton's Laws

1. Carts, Bricks, and Bands
2. Friction
3. Coffee Filter Physics

Common Misconceptions and Difficulties **See the complete toolkit at TPC's website for details.**

1. Mass vs. Weight
2. Force and the Direction of Motion

Standards:

A. Next Generation Science Standards (NGSS) – Grades 9-12
Performance Expectations – High School Physical Science: HS-PS2-1 and **HS-PS2-6**
Disciplinary Core Ideas – High School Physical Science: PS2.A.i and **PS2.B.iii**
Crosscutting Concepts: Structure and Function, **Stability and Change**, **Nature of Science: Order & Consistency in Natural Systems**
Science and Engineering Practices: #1, **#2**, and **#5**

B. Common Core Standards for Mathematics (CC) – Grades 9-12
Standards for Mathematical Practice, Quantities, Functions, and Linear, Quadratic, and Exponential Models. See the complete toolkit at TPC's website for details.

C. Common Core Standards for English/Language Arts (ELA) – Grades 9-12
Literacy in Science and Technical Subjects – Key Ideas & Details: RST11-12.3 and **RST.11-12.2**
Literacy in Science and Technical Subjects – Integration of Knowledge and Ideas: RST.11-12.7 and **RST.11-12.9**
Reading Standards: Literacy in Science and Technical Subjects – Range of Reading and Level of Text Complexity

D. College Ready Physics Standards (Heller and Stewart)
See the complete toolkit at TPC's website for details.