Teacher Toolkit - Air Resistance and Terminal Velocity

Objectives:

1. To explain the cause of air resistance.
2. To identify the variables that affect the amount of air resistance and to describe the manner in which those variables affect the amount of air resistance.
3. To describe the changes in speed, air resistance, net force and acceleration for an object falling under the influence of air resistance.
4. To explain why an object experiences a terminal velocity and why mass is an important factor affecting the terminal velocity value.
5. To compare and contrast free fall motion to the falling motion of an object experiencing air resistance.

Readings:

The Physics Classroom Tutorial, Newton's Laws Chapter, Free Fall and Air Resistance

Multimedia Physics Studios, Newton's Laws Section, Skydiving

Multimedia Physics Studios, Newton's Laws Section, The Elephant and the Feather

Interactive Simulations:

1. The Physics Interactives: Skydiving http://www.physicsclassroom.com/Physics-Interactives/Newtons-Laws/Skydiving
   This HTML5 Skydiving Interactive simulates the motion of a falling skydiver. The mass of the skydiver, the parachute size, and the initial height can be varied. Learners view the size of the two individual forces, the velocity, and the height over the course of the falling motion. This is a perfect tool for the 1:1 classroom.
2. Free Fall Air Resistance Model http://www.thephysicsfront.org/items/detail.cfm?ID=10002
   Powerful model for introductory physics. The blue ball falls under the influence of gravity alone; the red ball is influenced by air resistance. Students will have fun adjusting the air resistance, initial height, and velocity. *Available as a Java file only at this time.*

Video and Animation:

1. Discovery Education: Physics of Skydiving https://www.youtube.com/watch?v=ur40O6nQHsw
   Good choice for a lesson warm-up – this short video concisely illustrates the forces on a skydiver from the moment she jumps to the moment her feet hit ground. We like it because it's a very visual way to depict the effects of air resistance. The jumper reaches terminal velocity twice during her descent: once before she opens the parachute and again after she deploys the chute.
2. Elastic Science: James Bond and Terminal Velocity https://www.youtube.com/watch?v=lBk62CWsGok
   This film clip uses the opening sequence of the James Bond film "Moonraker" to illustrate the interaction of forces in skydiving. James Bond is pushed out of an airplane without a parachute. What will he do to overcome drag and increase his velocity to catch up to the villain with the parachute? The author has annotated the video to let students ponder the physics as they watch. Have fun with it!
3. Apollo 15 Historic Video: The Hammer and the Feather https://www.youtube.com/watch?v=03SPBXALJZI
   At the end of the Apollo 15 moon walk, Commander David Scott performed a live demonstration for TV cameras. He held out a geologic hammer and a feather and dropped them at the same time. Because the moon has no atmosphere (thus no air resistance), the feather and hammer both hit the ground at the same time. As Galileo had concluded hundreds of years before - all objects released together fall at the same rate of gravitational acceleration, regardless of mass.

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

1. The Physics Classroom, The Laboratory, Coffee Filter Skydiving Lab
2. The Physics Classroom, The Laboratory, From a Feather to an Elephant
3. The Physics Classroom, The Laboratory, Falling Body Spreadsheet Lab

Demonstration Ideas:

1. Feather and Coin in a Vacuum http://techtv.mit.edu/collections/physicsdemos/videos/9253-feather-and-coin-in-a-vacuum
   The free fall of coins and feathers are compared, first in a tube full of air, next with an evacuated vacuum pump. With air resistance, the feathers fall more slowly. In a vacuum, the objects fall at the same rate. This demo is also a Misconception Buster – See "Common Misconception #1" below.

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, question-specific help.

1. Newton's Laws of Motion, Ass't NL10 - Free Fall Acceleration
2. Newton's Laws of Motion, Ass't NL11 - Air Resistance

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

1. The Curriculum Corner, Newton's Laws, Air Resistance and Terminal Velocity
2. The Curriculum Corner, Newton's Laws, Skydiving
3. The Curriculum Corner, Newton's Laws, The Elephant and the Feather

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

1. The Calculator Pad, Newton's Laws of Motion, Problems #17, 19, 29

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

1. Science Reasoning Center, Newton's Laws, Coffee Filter Physics Lab

Real Life Connections:

1. Air Resistance in Orbit http://www.wired.com/2013/04/air-resistance-in-orbit/
   At the altitude of the International Space Station, there isn't much air. To stay in orbit, the ISS get regular "reboosts" from an Automated Transfer Vehicle. The boost causes the ISS to accelerate back up to proper orbit. But what happens to the astronauts when the ISS accelerates during a reboost? This 2-minute video shows you: if the astronauts don't anchor themselves, they will not move forward with the spacecraft – they appear to float backwards.
2. NASA Glenn Research Center: Factors that Affect Drag NASA: Aerodynamics Index
   Want to extend the learning on air resistance, or provide extra challenges for students with high interest? NASA's Glenn Research Center has a nicely-organized set of introductory resources on aerodynamics. Here's the home page:

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

1. Heavier objects fall faster because they experience less air resistance.
2. As an object approaches terminal velocity, both its velocity and acceleration decrease.

Elsewhere on the Web:

1. The Physics Classroom's Skydiving and Parachuting Gallery
   https://www.flickr.com/photos/physicsclassroom/galleries/72157625443219376/
   This Flickr gallery of photos serves as either a suitable introduction to the topic of skydiving and parachuting or an enrichment activity for students interested in the topic. The gallery features 18 incredible photos from Flickr photographers, each annotated by a short description written in a light-hearted and everyday language.

Standards: **(More details in Complete Toolkit at TPC's Teacher Toolkit website)**

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

B. Common Core Standards for Mathematics (CC) – Grades 9-12
Standards for Mathematical Practice:
Functions: F-IF.4 and **F-IF.6**
Linear, Quadratic, and Exponential Models F-LE.1.b and **F-LE.5**

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 Ideas RST.11-12.7 and **RST.11-12.9**
Literacy in Science and Technical Subjects –Level of Text Complexity RST.11-12.10

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