Teacher Toolkit - Free Fall and Acceleration of Gravity

Objectives:
1. To know the meaning of free fall and the conditions under which it occurs.
2. To know the value for the acceleration of gravity (g) and to relate this value to velocity-time information.
3. To relate the motion of a free-falling object to the graphical descriptions of its motion.
4. To use equations to calculate how fast and how far a free-falling object will move in a given amount of time.
5. To understand that the acceleration of gravity is independent of the mass of the free-falling object.

Readings:
The Physics Classroom Tutorial, 1-D Kinematics Chapter, Lesson 5

Interactive Simulations:
1. Concord Consortium: Was Galileo Right? http://concord.org/stem-resources/was-galileo-right
   This HTML5 graphing activity runs directly in a web browser to bring students a rich digital investigation of the effects of gravity on light and heavy objects.
2. Open Source Physics: Free Fall Model http://www.thephysicsfront.org/items/detail.cfm?ID=10001
   This very simple Java simulation lets students explore the motion of an object in free fall. The free fall is displayed as a motion diagram with position, velocity, and acceleration plots
3. Open Source Physics: Ceiling Bounce Model http://www.thephysicsfront.org/items/detail.cfm?ID=8385
   This simulation shows a ball launched by a spring-gun in a building with a very high ceiling. Graphs of position vs. time or velocity vs. time are automatically generated.
4. Open Source Physics: Free Fall Ride http://www.compadre.org/osp/items/detail.cfm?ID=11640
   This EJS (Easy Java Simulation) model combines the acceleration of gravity with the acceleration of an elevator moving up or down.
5. Open Source Physics: Free Fall Air Resistance http://www.thephysicsfront.org/items/detail.cfm?ID=10002
   In teaching free fall, it's good to be prepared for student confusion over why, for example, the free falling bowling ball hits the ground faster than the free falling leaf. After exploring this model, we recommend showing the Apollo 15 Hammer and Feather Drop (see Video section below).

Video and Animation:
1. Apollo 15 Hammer and Feather Video 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.
2. Cornell University: Slow Motion Water Drops http://people.cornellcollege.edu/dsherman/waterdrops.html
   This 3-minute video illustrates free fall by pumping green-dyed water droplets out of a reciprocating pump, then illuminating them with a strobe light.
3. Veritasium: Misconceptions About Falling Objects https://www.youtube.com/watch?v=_mCC-68LyZM
   Watch this all the way through! At first, it seems too simplistic for high school physics. But it packs a powerful punch at the end to prompt deep thinking about the difference between gravitational *force* and gravitational acceleration.
4. Galileo's Pisa Experiment http://paer.rutgers.edu/pt3/experimentindex.php?topicid=2&cycleid=7
   This learning cycle features three video experiments, organized sequentially for introducing concepts of free fall to introductory physics students.
5. MIT Tech TV: Strobe of a Falling Ball http://techtv.mit.edu/videos/831-strobe-of-a-falling-ball
   In this short video clip, a ball is dropped in front of a meter stick and lit by a strobe light. A long exposure photograph captures the position of the ball at each evenly spaced flash of light.
5. Free Fall Lab https://www.youtube.com/watch?v=o1eMQeKkc2s
   The Physics Classroom demonstrates the use of video analysis to analyze a falling object. The vertical acceleration and other trajectory characteristics are determined from graphical analysis.
6. Cargo Cut from a Hot Air Balloon http://www.compadre.org/Physlets/mechanics/prob2_10.cfm
   This animated problem presents the scenario of cargo free-falling from a position at rest. Given the coordinates, students are asked to calculate the velocity of the cargo before it was cut loose to fall.

Labs and Investigations: http://www.physicsclassroom.com/lab#1dk

1. The Physics Classroom, The Laboratory, Free Fall
2. The Physics Classroom, The Laboratory, Dune Buggy Challenge

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. Accompanied by detailed, question-specific help.

1. Newton's Laws, Ass't NL10 - Free Fall Acceleration

Concept Building Exercises: http://www.physicsclassroom.com/curriculum/1Dkin

1. The Curriculum Corner, 1-D Kinematics, Free Fall

Problem-Solving Exercises: http://www.physicsclassroom.com/calcpad/1dkin

1. The Calculator Pad, 1-D Kinematics, Problems #25 - #28

Science Reasoning Activities: http://www.physicsclassroom.com/reasoning/1dkin

1. Science Reasoning Center, 1-D Kinematics, Kinematics

Real Life Connections:

1. Problem-Based Learning: Bungee Jumping
   http://pbl.ccdmd.qc.ca/resultat.php?action=clicFiche&he=1050&afficheRecherche=99&IDFiche=157&endroitRetour=99&lesMotsCles=bungee%20jumping
   In this PBL scenario, students are given a rough design for a bungee jump from a 20-meter tower. They work cooperatively to figure out the parameters for a safe jump.

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

1. Acceleration of Gravity and Mass

Elsewhere on the Web:

1. Using Direct Measurement Videos to Teach Physics https://serc.carleton.edu/sp/library/dmvideos/index.html
   This resource, part of the SERC Project (Science Education Resource Center), describes how to implement direct measurement videos for active learning in introductory physics classrooms.

Standards:

A. Next Generation Science Standards
Disciplinary Core Ideas (DCIs) - Motion and Stability-Forces and Interactions
Performance Expectations HS-PS2-1
Science and Engineering Practices – Grades 9-12 Practice #3 and **#5**

B. Common Core Standards for Mathematics (CC) – Grades 9-12
High School Algebra – Creating Equations A-CED.4
High School-Functions F-IF.4 and **F-IF.8.b**
High School-Vector and Matrix Quantities N-VM.1 and **N-VM.3**

C. Common Core Standards for English/Language Arts (ELA) – Grades 9-12
Key Ideas and Details RST.11-12.2 and **RST.11-12.3**
Craft and Structure RST.11-12.4
Integration of Knowledge and Ideas RST.11-12.9
Range of Reading and 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.)