Terminal Velocity: Measurement, Forces and Motion

Investigate forces and motion and simple machines through measurements, car crashes, Mars exploration, and the Deep Horizon oil spill in the Gulf of Mexico. Includes connections to engineering design and math with STEM Professionals:

Dan Sawyer - Mechanical Engineer, National Institute of Standards and Technology (NIST)
Matt Brumbelow - Senior Research Engineer, Insurance Institute for Highway Safety (IIHS)
Kobie Boykins - Mechanical Engineer, NASA's Jet Propulsion Laboratory
Lisa Jones - Marine Biologist, National Oceanic & Atmospheric Administration (NOAA)

- ***Mission 1: Critical Measurements The Quest for Exactness***
- ***Mission 2: A Universe of Motion - Motion Velocity and Momentum***
- ***Mission 3: Fundamental Forces - Forces and the Laws of Motion***
- ***Mission 4: Make it Work - Work, Power and Machines***

Cross-Curricular Connections

Reading & Writing for Technical Subjects:

6-8.LST.2.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
9-10.LST.3.2: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
LST.1: Read and comprehend science and technical texts independently and proficiently and write effectively for a variety of discipline-specific tasks, purposes, and audiences
LST.2.1: Extract and construct meaning from science and technical texts using a variety of comprehension skills
LST.2.2: Determine the central ideas or conclusions of a text; provide an accurate, objective summary of the text.
LST.2.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
LST.3.1: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to texts and topics.
LST.4.1: Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
LST.7.1: Conduct short research assignments and tasks to answer a question (including a self generated question), or test a hypothesis, drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Literature Selections: *Burton's Zoom Va-Room Machine, Airman, The River, Carry on Mr. Bowditch*

Math: Algebraic Problem Solving, Using Ratios, Creating and Analyzing Graphs (Bar, Pie, Best-Fit Line, Slope), Unit Conversions, Measurement, Computation, Data Analysis

Social Studies: Innovations-Underwater Cables, The Renaissance man: Leonardo da vinci

Art: Physics of the Circus

Grades 4-5 Science Content & Engineering Standards

4.PS.1 Investigate transportation systems and devices that operate on or in land, water, air and space and recognize the forces (lift, drag, friction, thrust and gravity) that affect their motion. (Expeditions 1, 2, 3)

4.PS.2 Investigate the relationship of the speed of an object to the energy of that object. (Expeditions 1, 2)
4.PS.3 Investigate how multiple simple machines work together to perform everyday tasks. (Expedition 4)
4.PS.4 Describe and investigate the different ways in which energy can be generated and/or converted from one form of energy to another form of energy. (Expedition 1)
5.PS.1 Describe and measure the volume and mass of a sample of a given material. (Expedition 1)

Grades 6-8 Science Content & Engineering Standards

6.PS.1 Distinguish between the terms position, distance, and displacement, as well as, the terms speed and velocity. (Expedition 2)
6.PS.2 Describe the motion of an object graphically showing the relationship between time and position. (Expeditions 1, 2, 3)
7.PS.3 Investigate the Law of Conservation of Mass by measuring and comparing the mass of a substance before and after a change of state. (Expeditions 1, 3)
7.PS.2 Describe the properties of solids, liquids, and gases. Develop models that predict and describe changes in particle motion, density, temperature, and state of a pure substance when thermal energy is added or removed. (Expedition 3)
7.PS.4 Investigate Newton's first law of motion (Law of Inertia) and how different forces (gravity, friction, push and pull) affect the velocity of an object. (Expeditions 2, 3)
7.PS.5 Investigate Newton's second law of motion to show the relationship among force, mass and acceleration. (Expeditions 2, 3)
7.PS.6 Investigate Newton's third law of motion to show the relationship between action and reaction forces. (Expeditions 2, 3)
7.PS.7 Construct a device that uses one or more of Newton's laws of motion. Explain how motion, acceleration, force, and mass are affecting the device. (Expeditions 2, 3**)**
7.PS.8 Investigate a process in which energy is transferred from one form to another and provide evidence that the total amount of energy does not change during the transfer when the system is closed. (Law of conservation of energy. (Expeditions 2, 3)
6.ESS.1 Describe the role of gravity and inertia in maintaining the regular and predictable motion of celestial bodies. (Expedition 3)

Grades 9-12 Science Content Standards

PI.1.1 Develop graphical, mathematical, and pictorial representations (e.g. a motion map) that describe the relationship between the clock reading (time) and position of an object moving at a uniform rate and apply those representations to qualitatively and quantitatively describe the motion of an object. (Expedition 2)
PI.2.1 Develop graphical, mathematical and pictorial representations (e.g. a motion map) that describe the relationship between the clock reading (time) and velocity of an object moving at a uniformly changing rate and apply those representations to qualitatively and quantitatively describe the motion of an object. (Expedition 2)
PI.2.2 Describe the slope of the graphical representation of velocity vs. clock reading (time) in terms of the acceleration of the object. (Expedition 2)
PI.2.3 Rank the accelerations of objects in a system based on the slope of a velocity vs. clock reading (time) graphical representation. Recognize that the magnitude of the slope representing a negative acceleration can be greater than the magnitude of the slope representing a positive acceleration. (Expedition 2)
PI.2.4 Given a graphical representation of the position, velocity, or acceleration vs. clock reading (time), be able to identify or sketch the shape of the other two graphs. (Expedition 2)
PI.2.5 Qualitatively and quantitatively apply the models of constant velocity and constant acceleration to determine the position or velocity of an object moving in free fall near the surface of the Earth. (Expedition 2)
PI.3.1 Understand Newton's first law of motion and describe the motion of an object in the absence of a net external force according to Newton's first law. (Expeditions 2, 3)
PI.3.2 Develop graphical and mathematical representations that describe the relationship among the inertial mass of an object, the total force applied and the acceleration of an object in one dimension where one or more forces is applied to the object and apply those representations to qualitatively and quantitatively describe how a net external force changes the motion of an object. (Expedition 2)
PI.3.4 Understand Newton's third law of motion and describe the interaction of two objects using Newton's third law and the representation of action-reaction pairs of forces. (Expeditions 2, 3)
PI.4.3 Conceptually define "work" as the process of transferring of energy into or out of a system when an object is moved under the application of an external force and operationally define "work" as the area under a force vs. change in position curve. (Expedition 4)
PI.4.4 For a force exerted in one or two dimensions, mathematically determine the amount of work done on a system by an unbalanced force over a change in position in one dimension. (Expedition 4)
PI.5.1 For an object moving at constant rate, define linear momentum as the product of an object's mass and its velocity and be able to quantitatively determine the linear momentum of a single object. (Expedition 2)
PI.5.2 Operationally define "impulse" as the area under a force vs. change in clock reading (time) curve and be able to determine the change in linear momentum of a system acted on by an external force. Predict the change in linear momentum of an object from the average force exerted on the object and time interval during which the force is exerted. (Expedition 2)

PI.5.3 Demonstrate that when two objects interact through a collision or separation that both the force experienced by each object and change in linear momentum of each object are equal and opposite, and as the mass of an object increases, the change in velocity of that object decreases. (Expedition 2)
PI.5.4 Determine the individual and total linear momentum for a two-body system before and after an interaction (e.g. collision or separation) between the two objects and show that the total linear momentum of the system remains constant when no external force is applied consistent with Newton's third law. (Expeditions 2, 3)
PI.5.6 Mathematically determine the center of mass of a system consisting of two or more masses. Given a system with no external forces applied, show that the linear momentum of the center of mass remains constant during any interaction between the masses. (Expedition 2)