
explore the early solar system
map the surface of Vesta
InVestagate
appropriate for grades 6-9
keywords: asteroids, solar system, gravity, meteors, citizen science
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cosmoquest.org
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In**Vesta**gate

explore the early solar system
map the surface of Vesta

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and builds on the *AsteroidMappers: Vesta* citizen science project.

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Instructor's Guide

About Citizen Science

Citizen science is an engaging way for you and your students to have meaningful experiences in Science, Technology, Engineering, and Mathematics (STEM). Although there are many different types of citizen science projects happening all over the world, most of them can be thought of as

a collaboration of professional scientists and non-professional volunteers (citizen scientists) engaged in authentic scientific research.

Citizen scientists are ordinary people of all ages and interests, from weather observers and bird watchers to amateur astronomers and computer programmers! They experience the processes of science first hand as they help scientists to collect, analyze, and sometimes even interpret large amounts of data. They communicate their experiences and their findings to each other and to the public through blogs, forums, social media, and face-to-face meetings and conferences. Citizen science brings many, many opportunities to learn new things and to meet new friends.

Encourage your students to become citizen scientists! They will practice 21st Century Skills--critical thinking, communication, and collaboration--as well as science processes, all while learning amazing new things about the world around them. Exploring Vesta with CosmoQuest's *InVESTAgate* and Asteroid Mappers is a great way to get started. Enjoy!

Introduction

This unit focuses on the origins, composition, and features of small planetary bodies, particularly asteroids. It also introduces teachers and students to the *Vesta Mappers* citizen scientist project, which is part of the *CosmoQuest* online community. *CosmoQuest* seeks to create and support a vibrant, global community of teachers and learners who explore and share their universe through citizen science. The popular and successful citizen science projects it contains, (*Mercury Mappers, Moon Mappers,* and more), use the efforts of volunteers to help researchers analyze the flood of data that confronts them. Through citizen science projects, many unique scientific discoveries have been made, ranging from individual discoveries to those using classifications that depend on the input of everyone who has visited the site.

The arc of this unit is the development of an imaginary mission to the asteroid Vesta. In days one through four, students investigate the differences between planets, dwarf planets, asteroids, comets, and meteoroids. During days five through seven, students are challenged to learn all they can about the asteroid Vesta. In days eight through ten, they develop an engineering plan and experiment with models of technologies in the same way that scientists do to plan actual missions to an asteroid. Through this process, students will explore not only science content but science and engineering practices as well.

The content of the unit was intended for middle school students (grades 7-9), but is easily adapted for high school students. This unit provides links to background information for the teacher on the science of asteroids and the Solar System. The free resource *Exploring Meteorite Mysteries* (http://ares.jsc.nasa.gov/ares/education/program/expmetmys.cfm) gives a broad introduction to meteorites, asteroids, impact craters, and Solar System history. Information specifically about the Dawn mission can be found at http://dawn.jpl.nasa.gov/.

The CosmoQuest site includes information on the science goals of Asteroid Mappers (http://cosmoquest.org/x/asteroid-science/) and had a tutorial for the Asteroid Mappers software. It is strongly encouraged that the teacher familiarize himself or herself with the tutorial (http://cosmoquest.org/x/asteroid-mappers-tutorial/) before beginning the lesson with students.

Dawn and CosmoQuest have held a series of Hangouts on Air about the science being done at Vesta and the expected science to be done at Ceres when the spacecraft arrives in 2015. These interviews with asteroid scientists can be watched at any time from:
http://www.youtube.com/playlist?list=PLwuQGMPDT-L-qTZsNFCK2so0FFFIf-Sd7

The lessons in this unit follow the Biological Sciences Curriculum Study (BSCS) 5E instructional model. For more information on this inquiry lesson format, see http://www.bscs.org/bscs-5e-instructional-model.

Beginning the Unit

Technology Expectations
The overarching goal of the unit is to engage students in the authentic scientific research that is conducted through citizen science projects. Because *Vesta Mappers* is web-based, computer access is an implied necessity for this unit. The minimum number of computers is one per student team, bearing in mind that more than three students at a computer may result in student disengagement in the activity. In addition, a Promethean© Board, SMART© Board, or other classroom projection system will facilitate the presentation of the instructional material.

The *Vesta Mappers* project can be found at http://cosmoquest.org/projects/vesta_mappers/

Mapping Vesta
On Day Seven of the unit, you will be guiding your students through the process of marking craters by using the tutorial at the *Vesta Mappers* website. It is strongly recommended that you become familiar with the tutorial and the process of marking craters before you present the information to your students.

Student Teams
Before you begin teaching the unit, arrange your class in teams of three to five students. Many of the activities in the unit, like the process of science itself, require collaboration. As you assign the teams, be sure to mix skill and ability levels. Also keep in mind the number of available computers and arrange the teams to allow members easy access to them.

Student Journals
A good way to help students integrate their learning during the unit is to ask them to keep an *InVESTAgate!* Journal. The journal can include notes on vocabulary words and concepts, class assignments, and their own personal observations. The journals can also be used as a tool for assessment and a link to language arts skills.

Standards

The authors have chosen to use the Next Generation Science Standards, posted at http://www.nextgenscience.org/, as the basis for the lessons in this unit. Efforts were made in Cross-Curricular Links to include standards from the Common Core for math, language arts, and social studies.

Teaching the Unit

For each lesson, the "Engage" through "Evaluate" sections are planned to fill one 50-minute class period. You may find it necessary to adjust segments of the lesson to fit the needs of your class, your own teaching style, and the amount of time available. However, it is necessary to present the first four "Es" in the order listed to preserve the process of inquiry that the lesson intends.

Many of the lessons offer more than one activity to explore the content. These options are separated by the word "OR" in the plans. You may choose to use more than one option to re-teach difficult concepts or to extend the unit.

The ideas in the "Elaborate" and "Cross-Curricular Links" sections are meant to enrich the lesson and integrate learning in other subject areas. These activities are optional and could be provided as opportunities for homework or extra credit. If they are used as class activities, each would require one additional 50-minute class period.

Ending the Unit

The posttest provided may be too extensive for the purposes of your classroom. Feel free to use the test as a question bank and choose just those items appropriate for your students.

Unit Overview

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Introduction: Solar System Formation (accretion)	The Role of Gravity	It's Not a Planet?	Asteroids, Comets, and Meteoroids	Observing Asteroids	Asteroid Cratering	Asteroid Mappers
***Standards** ESS1.A, B; PS3B; CCC 3, 7; SEP 7; WHST.6-8.1,10	**Standards** ESS1.B; PS2.A; CCC 2, 7; SEP 4; MP8; WHST.6-8.7	**Standards** ESS1.B; CCC 6; RST.6-8.1, 7; WHST 6-8.9	**Standards** ESS1.A, B; PS2.A; CCC 3, 4; SEP 2-5; RST.6-8.3; MP 2, 4, 6	**Standards** ESS1.B; PS4.B; CCC 5; RST.6-8.3; WHST.6-8.2; MP 4, 5, 7	**Standards** ESS1.B; PS3.A, B, C; CCC 2, 7; SEP 8; RST.6-8.2, 3; WHST 7	**Standards** ESS1.B; CCC 1; SEP 4; RST.6-8.4; WHST.6-8.9
Engage Show picture of Vesta; Students write what they think it is; discuss findings	**Engage** Gravity misconception cards	**Engage** Classification activity involving random objects	**Engage** Comet demonstration	**Engage** *Asteroid Eros* - measuring asteroid features	**Engage**: Show NASA videos of impact and cratering of meteors	**Engage** Overview of Asteroid Mappers site on CQ
Explore *Active Accretion* OR *Building Blocks of Planets* activities	**Explore** Galileo experiment	**Explore** Ceres/Pluto Dwarf Planet Activity	**Explore** *Modeling Vesta* OR *Searching for Meteorites*	**Explore** *Looking at Asteroids*	**Explore** *Impact Craters*	**Explore** Students complete tutorial and map crater images on Vesta
Explain Administer pretest Planetary bodies build through accretion	**Explain** Gravity affects formation of planetary bodies	**Explain** Classification of planetary bodies	**Explain** Differences between comets, meteorites, and asteroids	**Explain** Meteorites and asteroids are evaluated using brightness	**Explain** Craters are formed when energy transfers from a moving mass to a planetary body.	**Explain** Teacher led discussion of findings and interpretation
Elaborate Solar system trading cards OR Solar system timeline	**Elaborate** *Follow the Falling Meteorite*	**Elaborate** Research the history of classification of Ceres and Pluto	**Elaborate** Interactive meteorite website	**Elaborate** Interactive asteroid games OR Vesta flip book	**Elaborate** *Crater Hunters*	**Elaborate** *DAWN*: *Vegetable light curves*
Evaluate Pre-test Teacher assesses journal entries	**Evaluate** Assess worksheets and journal entries	**Evaluate** Venn diagram of planet, asteroid and comet	**Evaluate** Vocabulary Quiz	**Evaluate** Concept Quiz	**Evaluate** Complete data table and questions	**Evaluate** Explain crater formation; support with facts from journals
Cross-Curricular Activities ELA: Argument for their ideas in engage activity	**Cross-Curricular Activities** ELA: Research Galileo and Newton's ideas of gravity	**Cross-Curricular Activities** ELA: Analysis of text in activity worksheets	**Cross-Curricular Activities** Art: Artistic display for the 3D model of Vesta	**Cross-Curricular Activities** Math: Challenge questions for *Asteroid Eros*	**Cross-Curricular Activities** Geography: Students research locations of crater on Earth	**Cross-Curricular Activities** Social Studies/ELA: Research and present the life of Kenneth Edgeworth or Gerard Kuiper

Day 8	Day 9	Day 10	Day 11	Day 12	Day 13
Expedition Asteroid: Vesta Landing	Expedition Asteroid: Mining Vesta	Expedition Asteroid: We Deliver!	The Universe is Out to Get You…or is it?	Review	Assessment
Standards ETS1-1, 1-4; SEP 1, 6; CCC 6; MP6, 7; WHST.6-8.2	**Standards** ESS1.B; ETS1-1,1-4; SEP 1,6; CCC6; MP6, 7; WHST.6-8.2	**Standards** ETS 1-2, 3, 4; SEP 1, 5, 6; CCC 6; MP6, 7, 8; WHST.6-8.1, 2	**Standards** ETS; SEP	**Standards** All	**Standards** All
Engage Introduce *Vesta Landing*	**Engage** Introduce *Mining Vesta*	**Engage** Introduce *We Deliver!*	**Engage** *TC3 Impact* power point	**Engage** Review game	**Engage** NA
Explore Design and build a lander	**Explore** Design and build a materials sorter	**Explore** Redesign lander to deliver a payload	**Explore** *Meteorite Asteroid Connection*	**Explore** NA	**Explore** NA
Explain Engineering and science are more alike than they are different	**Explain** Asteroids contain resources for space travel	**Explain** Cost benefit analysis helps determine if mining is worth the impacts	**Explain** Solar system is mostly empty space; it is rare for asteroids to hit Earth	**Explain** NA	**Explain** NA
Elaborate Interactive GRaND asteroid probe website	**Elaborate** How would your device work in microgravity?	**Elaborate** What are the potential impacts of mining on an asteroid?	**Elaborate** Finding impact craters with LANDSAT OR *Meteorite Asteroid Connection* activity A	**Elaborate** NA	**Elaborate** NA
Evaluate Vocabulary quiz; assess journals, completed task	**Evaluate** Assess journals and task completion	**Evaluate** Assess journals and task completion	**Evaluate** Assess student worksheets	**Evaluate** Assess students during review	**Evaluate** Administer post test
Cross-Curricular Links ELA: improve journaling skills by reporting on engineering design process	**Cross-Curricular Links** Social studies: compare and contrast mining challenges on Earth with those in space	**Cross-Curricular Links** Math: Evaluate data collected in engineering challenge to compare the cost-effectiveness of various mining operations	**Cross-Curricular Links** Current events: Research meteors and asteroids in the news ELA: Evaluate news for scientific accuracy	**Cross-Curricular Links** NA	**Cross-Curricular Links** NA

**Key to Standards:*
ESS - Next Generation Science Standards, Earth and Space Sciences
PS - Next Generation Science Standards, Physical Science
ETS - Next Generation Science Standards, Engineering and Technology
SEP - Next Generation Science Standards, Science and Engineering Practices
CCC - Next Generation Science Standards, Cross Cutting Concepts
MP - Common Core Standards, Mathematics Practices
WHST - Common Core Standards, Writing in History, Science, and Technical Subjects
RST - Common Core Standards, Reading in Science and Technical Subjects

Materials List

The items listed should be standard in most science classrooms or easily obtained. Please check the references in the day's lesson plans for the quantities suggested and adjust to fit the size of your classroom.

Lesson 1- Introduction: Solar System Formation

- Vesta journal for each student
- Picture of Vesta
- Active Accretion activity:
    - Student role cards
- Balloon Blocks of Planets activities
    - Balloons
    - Handful of Styrofoam pellets from packing material
    - One 22 cm glass pan
    - 50-100 small steel ball bearings (approx 4.5 mm diameter)
    - 5 medium ball bearings (approx 1 cm diameter)
    - 2 magnetic marbles
    - Round glass or aluminum pie or cake pan
    - Student worksheets

Lesson 2 – The Role of Gravity

- Gravity misconception cards
- Variety of object pairs such as ping pong balls, golf balls, marbles, small Styrofoam balls, paper wads, wooden blocks, brass cubes, feathers, sheets of paper
- Triple beam balance
- Student worksheets

Lesson 3 – It's Not a Planet?

- Objects to classify (such as button or beads)
- Student worksheets

Lesson 4 – Asteroids, Comets, and Meteoroids

- Dry ice
- Dirt
- Dish liquid
- Quart size baggie
- Searching for Meteorites activity
    - Balloons
    - Flour
    - Small pebbles
    - Water
    - Funnel measuring cup
    - Thin stick or skewer
    - Graph paper,
    - Student worksheets
- Modeling Asteroid Vesta in 3-D activity
    - Two different colors of clay or play dough

Lesson 5 – Observing Asteroids

- Metric rulers
- Calculators
- Pictures of asteroids
- Large nail or small piece of metal piping
- Metal file
- White paper
- 8 cm squares of construction paper (one each of red, black, blue, and white)
- Thermometers
- Incandescent light source
- 2 ring stands
- Clamps
- Cardboard
- 50 cm square of non-shiny black paper or cloth
- Student worksheets

Lesson 6 – Asteroid Cratering

- Plaster of Paris
- One large disposable pan or box (if completed as a demo)
- 3-4 small and deep containers such as margarine tubs or loaf pans (for groups)
- Mixing container
- Stirring sticks
- Water
- Projectiles (e.g. pebbles, steel shot, lead fishing sinkers, ball bearings)
- Powdered cocoa, gelatin, or fine sand
- Strainer
- Meter stick
- Student lab and data sheets

Lesson 7 – Expedition Asteroid: Vesta Landing

- Computer access for individual or pairs of students

Lesson 8

- Meter sticks
- Metric rulers or tape measures
- Target (Draw two concentric rings in the center of a standards paper plate)
- Paper cups
- Straws
- Tape
- Rubber bands
- String
- Index cards
- Paper clips
- Other appropriate building materials

Lesson 9 – Expedition Asteroid: Mining Vesta

- Paper cups
- Small paper clips
- Plastic beads (5 mm diameter or larger)
- Sand
- Building materials such as index cards, tape, magnet, string, straws, construction paper, rubber bands

Lesson 10 – Expedition Asteroid: We Deliver!

- Meter sticks
- Metric rulers or tape measures
- Target (Draw two concentric rings in the center of a standard paper plate)
- Paper cups
- Straws
- Tape
- Rubber bands
- String
- Index cards
- Paper Clips
- Other appropriate building materials

Lesson 11 – The Universe Is Out to Get You?... or is it?

- TC3 Impact power point
- Meteorite Asteroid Connection, Activity B (Long Road to Earth)
    - 1.2 meter square or larger piece of corrugated cardboard or very stiff poster board
    - 60 cm x 30 cm piece of corrugated cardboard or very stiff poster board
    - Push pins
    - Colored and regular pencils
    - String
    - Scissors
    - Ruler
    - Protractor
    - Clay-dough or similar substance in yellow or white
    - Magazine with colored pictures
    - Tables 1 and 2 from the lesson instructions
    - Razor knife (USE CAUTION with students and sharp objects)
- Meteorite Asteroid Connection, Activity C (Collision Course)
    - Craft or Butcher paper (60 cm x 60 cm) for each group
    - Pencil/pen and colored pencils (optional)
    - Rulers
    - Protractors
    - Table 4

Lesson 12 - Review

- Review game

Lesson 13 - Assessment

- Post-test

Vocabulary

Accretion (\ə-ˈkrē-shən\): accumulation under the influence of gravity and some minor forces.

Analyze (\ˈa-nə-ˌlīz\): to study something closely and carefully

Asteroid Belt (as-tuh-roid belt): area between Mars and Jupiter where thousands of asteroids orbit the sun.

Asteroid (as-tuh-roid): one of thousands of small (diameters under 1000 km) solid planetary bodies orbiting
the Sun; most orbit the Sun between Mars and Jupiter, but a few come closer as they cross the orbits of Earth and Mars.

Astronomer (\ə-ˈsträ-nə-mər\): one who studies the science of celestial bodies and their origins, magnitudes, motions, and compositions.

Astronomical Unit (\ˌas-trə-ˈnä-mi-kəl\, \ˈyü-nət\): a unit of length used in astronomy equal to the mean distance of the Earth from the Sun or about 93 million miles (150 million kilometers).

Bleb (blĕb): a small, usually rounded inclusion of one material in another.

Breccia (ˈbreCHēa): rock consisting of angular, coarse fragments embedded in a fine-grained matrix.

Carbonaceous chondrite (kahr-buh-ney-shuhs kon-drahyt): a class of primitive meteorites (unchanged since they first solidified about 4.6 billion years ago) that formed in the oxygen rich early solar system. Most of the metal found in them is in the form of silicates, oxides, or sulfides.

Ceres (sîr’ēz): a dwarf planet that orbits within the asteroid belt with a mean distance from the Sun of 2.6 astronomical units (260 million miles) and a diameter of 590 miles (950 km). It also can be considered the largest asteroid in the asteroid belt.

Chondrite (kon-drahyt): stony meteorite containing chodrules embedded in a fine grained matrix of pyroxene, olivine, and metallic nickel-iron.

Chondrule (ˈkändro͞ol): a small rounded body of various materials, chiefly olivine of pyroxene, found embedded in a usually fragmented matrix in certain of the stony meteorites.

Comet (ˈkämit): a small body of ice and dust circling the sun in an elliptical orbit; when it comes near the Sun gases are released that can form a tail or tails, generally pointing away from the sun.

Cost benefit analysis (\ˈkȯst\,\ˈbe-nə-ˌfit\,\ə-ˈna-lə-səs\): an analysis of the cost effectiveness of various alternatives to see whether the benefits outweigh the costs.

Crater (ˈkrātər): a hole or depression; most are roughly circular or oval in outline; on Earth most natural craters visible at this point in geologic time are of volcanic origin; on the Moon most craters are of impact origin.

Density (\ˈden(t)-sə-tē\): mass per unit volume; how much material is in a given space.

Design (\di-ˈzīn\): a plan or drawing that shows the look and function of a building or other object before it is built or made

Differentiation (dĭf ˈə-rĕnˈshē-ā'shən) : the processes that result in the separation of minerals during the cooling of magma.

Dwarf Planet (\ˈdwȯrf\, \ˈpla-nət\): a spherical celestial body revolving around the Sun, similar to a planet but not large enough to gravitationally clear its orbital region of most or all other celestial bodies.

Ecliptic Plane (i-ˈklip-tik, \ˈplān\): the plane defined by the orbit of the Earth around the Sun; most planets orbit in or near the ecliptic plane.

Ejecta (i-ˈjek-tə): material thrown out from and deposited around an impact crater.

Ellipse (i-ˈlips, e-): (elliptical) a closed curve of oval shape.

EM Spectrum (EM, \ˈspek-trəm\): the entire range of wavelengths or frequencies of electromagnetic radiation ranging from gamma rays to the longest radio waves and including visible light.

Force (\ˈfȯrs\): a push or pull upon an object resulting from the object's interaction with another object; any of various factors that cause a body to change its speed, direction or shape.

Friable (ˈfrī-ə-bəl): easily crumbled rock fragments.

Gravity (\ˈgra-və-tē\): a force of attraction pulling any two tings toward each other, dependent on the mass of the objects.

Impact (\im-ˈpakt\): the forceful striking of one body, such as a meteorite, against another body such as a moon or planet.

Impact Crater (\im-ˈpakt\, \ˈkrā-tər\): a depression on the surface of a planet, moon, or other solid body in the Solar System formed when a smaller body strikes its surface with some force. This is in contrast to volcanic craters which result from explosions or internal collapse.

Inclusions (\in-ˈklü-zhəns\): a fragment of another rock enclosed in a rock.

Interpret (\in-ˈtər-prət, -pət\): explain the meaning of

Investigation (\in-ˈves-tə-ˌgāshən\): a detailed inquiry or systematic examination

Light (\ˈlīt\): electromagnetic radiation across all wavelengths (see also EM spectrum). The wavelengths that can be seen by the human eye are called Visible Light.

Magnetism (\ˈmag-nə-ˌti-zəm\): a property possessed by certain bodies, whereby under certain circumstances, they repel or attract one another according to determined laws and ultimately due to the movement of electrons.

Mass (\ˈmas\): the amount of matter in a given object.

Matrix (\ˈmā-triks\): the smaller sized grains in a rock, where the rock consists of large grain fragments surrounded by smaller grains

Metals (\ˈme-tᵊls\): any of a class of substances that typically are opaque, are good conductors of electricity, and often have a shiny luster like gold.

Metamorphism (\-ˈmȯr-ˌfi-zəm\): the process by which rocks are altered in composition, texture, or internal structure, by extreme heat, pressure, or chemical substances.

Meteor (\ˈmē-tē-ər, -ˌȯr\): relatively small body of matter traveling through interplanetary space

Meteorite (ˈmē-tē-ə-ˌrīt): a metallic or stony (silicate) body that had fallen on Earth, Moon or other planetary body from space.

Meteoroid (ˈmē-tē-ə-ˌrȯI;d): a piece of interplanetary matter that is smaller than a kilometer and often only millimeters in size. Most meteoroids that enter the Earth's atmosphere are so small that they vaporize and never reach the planet's surface.

Model (\ˈmä-dᵊl\): a preliminary work or construction that serves as a plan for a product; scientific models can be material, visual, mathematical, or computational and are often used in the construction of scientific theories.

Olivine (\ˈä-lə-ˌvēn\): a usually greenish mineral that is a complex silicate of magnesium and iron.

Orbit (\ˈȯr-bət\): the path of an object in space moving about another under gravitational attraction.

Organic (\ȯr-ˈga-nik\): compounds of carbon, hydrogen, and oxygen that form complex molecules. (They may or may not be from living organisms.)

Perihelion (\ˌper-ə-ˈhēl-yən\): the point in the path of a celestial body (as a planet) that is nearest to the Sun

Planet (\ˈpla-nət\): any of the eight large celestial bodies revolving around the Sun and shining by reflected light.

Platy (ˈplā-tē): the texture of a rock that is composed of flat minerals or rock fragments.

Porous (\ˈpȯr-əs\): contains open or void spaces between solid materials.

Primitive (\ˈpri-mə-tiv\): of, belonging to, or seeming to come from an early time in the very ancient past

Projectile (\prə-ˈjek-tᵊl, -ˌtī(-ə)l\): object that impacts a surface.

Prospector (\ˈprä-ˌspektor\): one who explores an area for mineral deposits, water, or other resources.

Pyroxene (\pī-ˈräk-ˌsēn, pə-\): any group of igneous-rock forming silicate minerals that contain calcium, sodium, magnesium, iron, or aluminum, usually occur in short prismatic crystals or massive form; they vary in color from white to dark green or black

Reflectance (\ri-ˈflek-tən(t)s\): the amount of light of a particular color reflected by a surface, divided by the amount of light of the same color that strikes the surface.

Regolith(ˈre-gə-ˌlith): loose, unconsolidated rock, mineral, and glass fragments on the Moon and some other planetary bodies; this debris is produced by impacts and blankets the surface.

Retrograde (\ˈre-trə-ˌgrād\): a motion in a direction contrary to that of the general motion of similar bodies and especially east to west among the stars; also, having or being a direction of rotation or revolution that is clockwise as viewed from the north pole of the sky or a planet; an orbit that moves in the opposite direction of the Earth's orbit.

Rim (\ˈrim\): the border of a land form, such as the curved edge surrounding the top of a crater.

Solar Nebula (\ˈsō-lər, -ˌlär\,\ˈne-byə-lə\): gravitational accumulation of solid particles and dust around the sun; stars have these nebulae early on in their histories and they are eventually collected into planets, or pushed away by the radiation of the sun.

Sphere (\ˈsfir\): an object that is round or almost round in all dimensions like a ball.

Static Electricity (\ˈsta-tik\,\i-ˌlek-ˈtri-sə-tē, ē-ˌ, -ˈtris-tē\): electricity that consists of isolated motionless charges (as those produced by friction)

Terrain (\tə-ˈrān *also* te-\): area of the surface with a distinctive physical or geological character.

Texture (\ˈteks-chər\): general physical appearance of a rock.

Trojan asteroid (\ˈtrō-jən\, \ˈas-tə-ˌrȯid\): an asteroid belonging to one of two groups that orbit the sun at the same distance as Jupiter.

Unconsolidated (\ˈən- kən-ˈsä-lə-ˌdāt d \): materials loosely packed but not cemented to each other.

Unfractured (\ən- ˈfrak-chər, -shər d)\: does not contain breaks or cracks.

Velocity (\və-ˈlä-sə-tē, -ˈläs-tē\): rate of motion in a specific direction, measured in distance per time.

Vesicles (\ˈve-si-kəl s\): bubble-shaped cavities in a volcanic rock formed by expanding gases.

Vesta (\ˈves-tə\): one of the largest asteroids in the Solar System

Volatiles (ˈvä-lə-tᵊ s): chemical elements that enter a gas phase at relatively low temperatures.

Featured Links

Day One - Solar System Formation
NASA's Discovery and New Frontiers Programs http://discovery.nasa.gov/
Exploring Meteorite Mysteries http://ares.jsc.nasa.gov/ares/education/program/expmetmys.cfm
Solar System Trading Cards at http://amazing-space.stsci.edu/resources/explorations/trading/directions.html

Day Two - The Role of Gravity
Video of gravity demonstrations http://blogs.howstuffworks.com/2011/03/09/how-gravity-works-a-nice-explanation-of-peoples-misconceptions-about-the-force-of-gravity/
Exploring Meteorite Mysteries http://ares.jsc.nasa.gov/ares/education/program/expmetmys.cfm

Day Three - It's Not a Planet?
NASA's Dawn Teacher's Guide http://nasawavelength.org/resource/nw-000-000-001-471/

Day Four - Asteroids, Comets, and Meteoroids
Comet model http://www.astro.virginia.edu/dsbk/resources.php
Exploring Meteorite Mysteries http://ares.jsc.nasa.gov/ares/education/program/expmetmys.cfm
Modeling Asteroid Vesta http://dawn.jpl.nasa.gov/DawnKids/SAYourMissionVesta3D.pdf
Interactive rock/meteorite identification website http://dawn.jpl.nasa.gov/Meteorite/index.asp

Day Five - Observing Asteroids
Exploring Meteorite Mysteries http://ares.jsc.nasa.gov/ares/education/program/expmetmys.cfm
Interactive asteroid games http://www.killerasteroids.org/
Vesta Flip Book http://dawn.jpl.nasa.gov/dawnkids/SAYourMissionFlipbook.pdf

Day Six – Asteroid Cratering
Impact crater on Comet Tempel 1 http://solarsystem.nasa.gov/deepimpact/gallery/animation.cfm
Exploring Meteorite Mysteries http://ares.jsc.nasa.gov/ares/education/program/expmetmys.cfm

Day Seven - Mapping
CosmoQuest Vesta Mappers http://cosmoquest.org/
Vegetable Light Curves http://dawn.jpl.nasa.gov/DawnClassrooms/light_curves/

Day Eight - Expedition Asteroid Part 1
GRaND asteroid probe interactive website http://dawn.jpl.nasa.gov/technology/GRaND_inter.asp

Day Eleven - The Universe Is Out to Get You
TC3 Impact power point http://dps.aas.org/files/dps/education/dpsdisc/2009/TC3Impact.ppt
Exploring Meteorite Mysteries http://ares.jsc.nasa.gov/ares/education/program/expmetmys.cfm
Finding impact craters with LANDSAT http://craters.gsfc.nasa.gov/index.htm

Day One - Solar System Formation

Objective:
Students will *construct a model* to show the process of accretion in solar system formation.

Next Generation Science Standards:
For complete description of each standard, click on the links below.
*ESS1.A: The Universe and Its Stars
*ESS1.B: Earth and the Solar System
*PS3.B: Conservation of Energy and Energy Transfer
*CCC 3: Scale, Proportion, and Quantity
*CCC 7: Stability and Change
*SEP 7: Engaging in Argument from Evidence

Common Core Standards:
*ELA/Literacy WHST.6-8.1: Write arguments focused on discipline content.
*CCSS.ELA-Literacy.WHST.6-8.10

Materials:
Journal for each student, picture of Vesta
Active Accretion activity: student role cards
Building Blocks of Planets activities: balloon, handful of Styrofoam pellets from packing material, one 22 cm glass pan, 50-100 small steel ball bearings (approximately 4.5 mm diameter), 5 medium ball bearings (approximately 1 cm diameter), 2 magnetic marbles, round glass or aluminum pie or cake pan, student worksheets

Engage:
Using all the drama and mystery you can muster, tell students you have received an unusual picture in the mail: you don't know whom it's from, and the note that came with it says only "Important - Find out all you can." Display a picture of Vesta, (one where it looks as much like a potato as an asteroid), and ask students to write down what they think it is in their new journals. Lead a class discussion in which students discuss their opinions and evidence with each other and the class as a whole. List their ideas on the board. Point out any ideas that suggest it's some type of small body in space and say, "I have an activity that can help us explore this idea."

Explore:
Follow the directions for "Active Accretion" from *NASA Discovery and New Frontiers* (http://discovery.nasa.gov/education/eduClassroom.cfml) programs. This is a game students play in a large area to demonstrate the accretion of particles to form solar system bodies **OR**
Follow the directions for *Exploring Meteorite Mysteries* (http://ares.jsc.nasa.gov/ares/education/program/expmetmys.cfm) Lesson 10, "Building Blocks of Planets," activities B & C. These two activities use marbles and other objects on a pie pan to model accretion.

Explain:
Administer pretest.
Students copy vocabulary, definitions, and concepts into their Asteroid Journals.
Vocabulary:
Astronomer, chondrule, chondrite, sphere, matrix, solar nebula, accretion, metamorphism, differentiation, organic, static electricity, magnetism
Concepts:
- Planetary bodies build by collecting smaller pieces of unrelated materials such as star dust etc. (accretion)

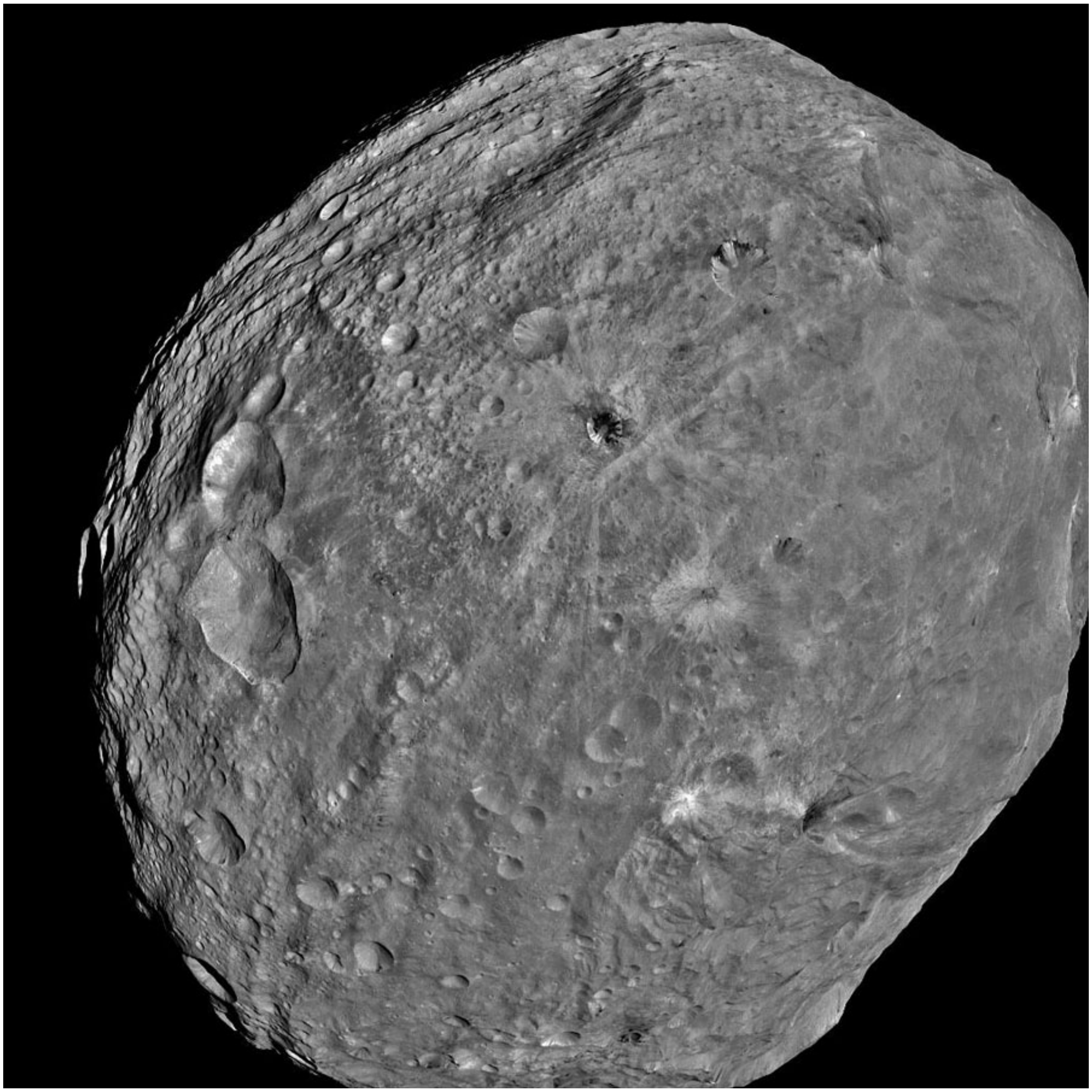
- Bodies are modified by differentiation and/or metamorphism

Make copies of the diagram from page 16 of "Meteorites: Clues to Solar System History" information pages, (found in the *Exploring Meteorite Mysteries* materials), so students can tape it into their journals.

Elaborate:
Research and prepare a timeline for the formation of the solar system. OR Copy and trade Solar System Trading Cards at http://amazing-space.stsci.edu/resources/explorations/trading/directions.html

Evaluate:
Teacher assesses journal entries

Cross-Curricular Link:
English Language Arts: Students write arguments to support their ideas during the engage activity. They also begin writing observations, notes, and writing assignments in their Asteroid Journals. These writing activities will continue throughout the unit.



Astronomy Picture of the Day
2011 August 2
Asteroid Vesta Full Frame
Image Credit: NASA, JPL-Caltech, UCLA, MPS, DLR, IDA

Explanation: Why is the northern half of asteroid Vesta more heavily cratered than the south? No one is yet sure. This unexpected mystery has come to light only in the past few weeks since the robotic Dawn mission became the first spacecraft to orbit the second largest object in the asteroid belt between Mars and Jupiter. The northern half of Vesta, seen on the upper left of the above image, appears to show some of the densest cratering in the Solar System, while the southern half is unexpectedly smooth. Also unknown is the origin of grooves that circle the asteroid near its equator, particularly visible on this Vesta rotation movie, and the nature of dark streaks that delineate some of Vesta's craters, for example the crater just above the image center. As Dawn spirals in toward Vesta over the coming months, some answers may emerge, as well as higher resolution and color images. Studying 500-km diameter Vesta is yielding clues about its history and the early years of our Solar System.

Day Two - The Role of Gravity

Objective:
Students will analyze the affect that gravity has on falling objects, and explore the role gravity plays in the formation of solar systems.

Next Generation Science Standards
*ESS1.B: Earth and the Solar System
*PS2.A: Forces and Motion
*CCC 2: Cause and Effect
*CCC 7: Stability and Change
*SEP 4: Analyzing and Interpreting Data
MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Common Core Standards
CCSS.ELA-Literacy.WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.
*CCSS.Math.Practice.MP8 Look for and express regularity in repeated reasoning.

Materials:
Gravity misconception cards, a variety of object pairs such as ping pong balls, golf balls, marbles, small Styrofoam balls, paper wads, wooden blocks, brass cubes, feathers, sheets of paper, triple beam balance, meter stick, student worksheets

Engage:
Today's lesson builds on the mysterious picture and note from day one. Now that the students have an idea that the picture is a space object, and the object was formed through accretion, they need to learn how gravity affects all objects in the solar system.
Follow the directions for the Gravity Misconceptions activity to help students uncover their own misconceptions about this force.

Explore:
Follow the directions for "Gravity Pulls You Down," a recreation of Galileo's gravity experiment.

Explain:
Students copy vocabulary, definitions, and concepts into their Asteroid Journals.
Vocabulary:
Gravity, mass, force, meteorite, terrain, velocity, impact
Concepts:
- Gravity was a force present in formation of the solar system
- Gravity affects planetary bodies

Elaborate:
Exploring Meteorite Mysteries http://ares.jsc.nasa.gov/ares/education/program/expmetmys.cfm Lesson 2, "Follow the Falling Meteorite," features three activities that introduce triangulation as a method for finding pieces of asteroids that fall to Earth.

Evaluate:
Journal entries and student worksheets from the activity can be used as assessment tools for this lesson.

Cross-Curricular Link:
English Language Arts: Research Galileo and Newton's ideas of gravity, contrasting and comparing the two theories.

Gravity Misconceptions

Procedure

1. Before class, print the gravity statements below and glue or tape to index cards.

2. Distribute one card to each pair of students.

3. Ask the students to discuss the statement on the card and decide if it is true or false.

4. Tell the students to write a short paragraph explaining their answers in their journals.

5. Collect the cards and continue with the lesson as described in the ***Day 2*** lesson plan.

6. At the end of the activity, discuss each of the statements with the students. Have the students state their original answer and any changes they would like to make now that they have completed the activity.

7. Share the correct answers with the students.

Gravity Statement Cards

A pebble dropped down a hole through the center of the Earth would stop at the center.	The human body can handle increased g-forces in activities such as airplane acrobatics and space training.	Although you cannot feel it, there is a gravitational attraction between you and the person sitting next to you.
Gravity is caused by movement or magnetic fields.	The gravitational force of the Earth on you is larger than the force you exert on the Earth.	Planets with thin atmospheres must have little gravity.
Gravity keeps the planets in orbit around the Sun.	Some roller coasters include increased g-forces.	Planets far away from the Sun have less gravity.

Gravity is stronger between the most distant objects.	Space shuttle astronauts are weightless because there is no gravity above Earth.	Tides are caused by the rotation of the Earth and the gravitational effects of the Moon and Sun.
Being on a space station can cause problems such as bone and muscle loss.	Heavier objects fall faster than lighter objects.	A galaxy 13 billion light years away is gravitationally attracted to you.
Without gravity some bugs (bacteria) get tougher.	The Moon has no gravity.	There is no gravity in space.
Gravity guides the growth of plants.		Gravity is a force.

Gravity Misconceptions Key

1. Gravity is caused by movement or magnetic fields. (False)
   Gravity is related to the masses of objects (not just the Earth!) and the distance between objects. It has nothing to do with magnetic fields or movement (in most cases.)
2. The Moon has no gravity. (False)
   The Moon is an object with mass, and thus it must have gravity! The gravity on the surface of the Moon is 1/6th that of the gravity on the surface of the Earth.
3. Planets with thin atmospheres must have little gravity. (False)
   The atmosphere has no effect on the gravity of a planet. Although smaller planets tend to lose their atmosphere faster due to lower gravity, there are many other factors that come into play.
4. Planets far away from the Sun have less gravity. (False)
   Planets further from the Sun feel less gravity from the Sun than planets closer in, but their own gravity only depends on their mass and size.
5. Gravity is stronger between the most distant objects. (False)
   Gravity is weaker between objects as they move away from each other!
6. Space shuttle astronauts are weightless because there is no gravity above Earth. (False)
   There is gravity in space! In fact, the gravity felt by astronauts in low-Earth orbit is only slightly less than the gravity felt on Earth. Astronauts (and all of their stuff) appear weightless because they and the spacecraft are actually falling to Earth with the same speed and acceleration.
7. There is no gravity in space. (False.)
   Gravity is everywhere! Massive objects exert gravitational forces on each other across unimaginable distances.
8. A pebble dropped down a hole through the center of the Earth would stop at the center. (False)
   Ignoring air resistance and rotation, a pebble dropped through the center of the Earth would fall faster and faster until it reached the center, at which point it would start moving slower until it reached the other side where it would stop and reverse its motion, theoretically moving back and forth forever. In this way, it is like a pendulum. This is because the pebble is only acted upon by the mass of the Earth interior to its present radius, and the acceleration due to gravity depends on that mass and the distance to the center.
9. The gravitational force of the Earth on you is larger than the force you exert on the Earth. (False)
   According to Newton's third law of motion, when one object exerts a force on another, the other exerts an equal but opposite force on the first object. So, you exert an equal amount of force on the Earth as it exerts on you!
10. Heavier objects fall faster than lighter objects. (False)
    In the absence of air resistance, all objects fall with the same acceleration towards a planet's surface, thus hit at the same time. This was demonstrated on the airless Moon by Apollo 15 commander David Scott when he dropped a hammer and a feather from the same height and they hit the surface at the same time.
11. A galaxy 13 billion light years away is gravitationally attracted to you. (True)
    Gravity gets much weaker with distance, but, theoretically, the gravitational force between two objects never goes to zero. So, there is a teeny, tiny amount of gravitational

attraction between you and everything in the Universe, no matter how distant (ignoring the extreme effects of dark energy).

12. Although you cannot feel it, there is a gravitational attraction between you and the person sitting next to you. (True)
    Just as gravity never goes to zero over large distances, there is always a gravitational attraction between any two objects with mass. It is too weak to feel, but there is a gravitational force between you and every object around you!
13. Gravity keeps the planets in orbit around the Sun. (True)
    Gravity is responsible for most large structures in the Universe. Without gravity, the planets would careen out of orbit in a straight line out of the Solar System.
14. Without gravity some bugs (bacteria) get tougher. (True)
    Studies done on the bacteria salmonella show that it can get up to three times more harmful when in a "weightless" environment such as a space station. Why? Scientists aren't sure, but the lack of gravitational effects changed how the genes and proteins acted in the bacteria, making test subjects (mice) sick faster and with less exposure than their Earth-bound counterparts.
15. Tides are caused by the rotation of the Earth and the gravitational effects of the Moon and Sun. (True)
    The Moon has a slightly stronger gravitational force on the side of the Earth facing it than the sides of the Earth away from it. This causes the oceans to swell up in some areas, and sink down in others as the Moon pulls on it. Because of Earth's constant rotation and the Moon's orbit around the Earth, the tides aren't perfectly aligned with the position of the Moon.
16. The human body can handle increased g-forces in activities such as airplane acrobatics, space training, and drag races. (True)
    The effects of gravity can be simulated by acceleration in any direction. In such cases, we call these g-forces. Humans going into space regularly deal with g-forces of 3 or 4 times Earth's gravity, and astronaut Gus Grissom was able to withstand g-forces of up to 16 times Earth gravity in simulators in the 1960s.
17. Some roller coasters include increased g-forces. (True)
    This has the same explanation as for #16. Roller coasters are exciting particularly because they subject visitors to g-forces they wouldn't otherwise feel in their every day lives.
18. Gravity guides the growth of plants. (True)
    Plants sense gravity so that their roots can grow into the ground and the shoots grow up towards the surface. Gravity is sensed by the presence of special cells in the root tips with small, pebble-like structures called "statoliths." These help the plant "know" which way is down.
19. Being on a space station can cause problems such as bone and muscle loss. (True)
    The human body evolved to exist on the surface of planet Earth. When in a "weightless" environment such as a space station, the body will lose muscle and bone mass that are no longer needed for walking or standing upright in a normal gravity environment. Astronauts need to train for many hours on special workout equipment to keep up their muscle mass for an easy transition to life back on Earth.
20. Gravity is a force. (True)
    A force is an influence that causes an object to change in some way. Gravity is the force that acts on the property of mass.

Teacher Page

Gravity Pulls You Down

Adapted from "Gravity Gets You Down" by Mary C. Cahill

Objective:

- To determine if objects of different masses fall at the same acceleration.
- To explore the concept of gravity.

Concepts:

1. Without air resistance, all objects would fall with the same acceleration regardless of mass.
2. Gravity is the force that causes objects to fall.
3. Air resistance, a type of friction, works against gravity to decrease the acceleration of a falling object.
4. Note that, excluding air resistance, each object falls with the same acceleration or rate change of speed as it falls. This is not to say that they travel at the same speed or velocity. However, objects dropped at the same height with no initial velocity will have the same final velocity as they hit the ground.

Materials:

- A variety of object pairs, such as balls of different sizes and weights. Objects may include: a ping pong ball, golf ball, marble, small Styrofoam ball, paper wad (size of a golf ball, wooden block, brass cube.
- Objects, such as a feather or sheet of paper, that encounter more resistance
- Triple beam balance
- Meter stick

Procedure:

1. Ask your students if they predict that a heavier or larger object, if dropped from a height, will fall to Earth faster than a smaller or lighter object. Tell them that Galileo Galilei (1564-1642) performed a famous experiment that they are going to replicate in order to confirm or refute their prediction.
2. Give each lab group a variety of objects to experiment with.
3. Instruct lab groups to discuss their predictions and write them on their lab sheets. Remind them that they should only test one variable at a time, such as mass or height. They should drop each object, not throw them, so that the initial speed of each fall is zero at the starting height.
4. Have students experiment with object pairs by, first, measuring and recording their mass, and then dropping them while standing on a desk, chair or stepstool. Some students in the group should observe carefully to see whether one object reached the floor before another or both objects reached the floor at the same time. Students should carefully record their

results on their charts. (Students should find that balls of different sizes and weights fall at the same rate of speed.)

5. Have students drop a piece of paper or feather and a ball from the same height. They should discover that the feather or sheet of paper will fall more slowly than the ball. Suggest that they bunch the sheet of paper up into a ball and drop it and the ball from the same height. They should discover that they fall at the same rate of speed. If they drop a flat piece of paper and bunched piece of paper from the same height, the sheet should fall more slowly.
6. Ask students to discuss the possible reasons for these results. They should conclude that air resistance, a type of friction, is slowing down the piece of paper and feather.
7. Ask students what they think would happen if they performed the same experiment in a vacuum tube, which has no air, or on the surface of the Moon. (The feather would fall at the same rate of speed as a brick or ball.)
8. Have students complete their lab worksheets.
9. Show students the video of astronauts experimenting on the Moon (http://www.youtube.com/watch?v=5C5_dOEyAfk) OR the video which shows the Moon experiment as well as an experiment in a vacuum and student demonstration (http://blogs.howstuffworks.com/2011/03/09/how-gravity-works-a-nice-explanation-of-peoples-misconceptions-about-the-force-of-gravity/).

Elaborate:

Discussion Questions

1. Describe how the human body has adapted to the force of gravity on Earth over time. How might it have evolved if gravity had not been present?
2. Compare and contrast the force of gravity on Earth with one of the other planets in our Solar System. Which planet has a stronger gravitational force? What would be the effects on astronauts' bodies when visiting this planet for an extended period of time?
3. Describe the gravity experiments conducted by Galileo, Newton, and Cavendish. How were these experiments similar? How did these scientists build on each other's research and observations to make their own discoveries?
4. A roller coaster is usually designed to give its riders the sense of defying the force of gravity. Sometimes the back car is moving slightly faster than the others because of the acceleration of gravity. Other times the first car is going slightly faster. Keeping that in mind, which seat in the roller coaster is the scariest? How might a roller coaster designer make a coaster that gives the greatest sensation to the passengers?

Student Lab Sheet
Name: ________________
Date: ________________

Lab Sheet: Gravity Pulls You Down

Objective: To see if objects of different sizes and masses fall at the same rate.

Materials: Triple beam balance, meter stick, 10 objects supplied by your teacher

Procedure:

1. Using a triple beam balance, find the mass of each object at your lab station and record the mass on your data table.
2. Choose a light and heavy object and predict which one will reach the floor first when dropped from the same height. Record your prediction.
3. Have one team member stand on a chair or stool holding the light object in one hand and the heavy object in the other. Measure the height from the floor to the objects.
4. Release both objects at the same time and observe when each object hits the floor. (Two team members may have to sit on the floor to make an accurate observation).
5. Record the result and repeat 2 more times.
6. Choose two other objects and repeat steps #2-5.
7. Were your predictions correct?
8. Drop a piece of paper and ball from the same height. Predict which will hit the floor first. Record result.
9. Bunch the sheet of paper into a ball and drop the paper and a ball. Record the result.

Questions:

1. Explain in a paragraph what happened for each pair of objects that you dropped.

____
____
____
____
____
____

2. Were your predictions correct? ____

3. Explain why you think that you got the result that you did?

____
____
____
____

4. Describe what happened when you dropped the sheet of paper and ball. What happened when you bunched the paper and repeated the experiment? Explain.

____
____
____
____
____

5. What force(s) were acting on the objects? ___________________________________

Mass of Objects

List objects and mass.

1. ______________
2. ______________
3. ______________
4. ______________
5. ______________
6. ______________
7. ______________
8. ______________
9. ______________
10. ______________

First Pair Data Table

Objects	Mass (grams)	Prediction	Which Landed First Trials		
			#1	#2	#3
1					
2					

Second Pair Data Table

Objects	Mass (grams)	Prediction	Which Landed First Trials		
			#1	#2	#3
1					
2					

Third Pair Data Table

Objects	Mass (grams)	Prediction	Which Landed First Trials #1	#2	#3
1					
2					

Fourth Pair Data Table

Objects	Mass (grams)	Prediction	Which Landed First Trials #1	#2	#3
1					
2					

Day Three - It's Not a Planet?

Objective:
Students will classify various objects in the Solar System as planets, dwarf planets, or asteroids.

Next Generation Science Standards
*ESS1.B: Earth and the Solar System
*CCC 6 Structure and Function
SEP 1 Asking Questions and Defining Problems

Common Core Standards
*CCSS.ELA-Literacy.RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.
*CCSS.ELA-Literacy.RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
CCSS.ELA-Literacy.WHST.6-8.9 Draw evidence from informational texts to support analysis reflection, and research.

Materials:
Objects to classify, (such as buttons or beads), student worksheets

Engage:
1. Remind students of what they have learned so far:
   - Everything in the Solar System was formed by collisions of grains that were then held together by the forces of gravity.
   - More collisions built larger and larger bodies in orbit around the Sun.
   - Gravity is the attractive force between any two objects.
   - The more mass an object has, the greater its gravity.

2. Bring up the picture of Vesta and the "mysterious note" from day one. Remind them that they haven't yet decided for certain what it is. Tell them that today they will learn how to classify the bigger objects in space.
3. To introduce the concept of classification, give each team of students a box of about twelve objects that are similar but different: different sizes and colors of buttons, for example. Ask the teams to divide the objects into three or four groups, based on the ways they are the same and the ways they are different. Ask students to write descriptions of their groupings in their journals.
4. Inform the class that they will be classifying Solar System objects. Just as they did with the items in the box, Solar System objects are classified based on their **physical characteristics**.

Explore:
Use the "Ceres and Pluto: Dwarf Planets" activity from NASA's *DAWN Teacher's Guide* http://nasawavelength.org/resource/nw-000-000-001-471/ to introduce the classification of planets, dwarf planets, and asteroids.

Explain:
Ask students to classify the mystery picture, citing evidence from their investigations.
Students add definitions and concepts to their Asteroid journals.
Vocabulary:
dwarf planet, planet, asteroid, Trojan asteroid
Concepts:
- Classification of planetary bodies depends on the object's orbit around the Sun and shape of the body.

- Classification is also based on whether the planetary body is a satellite and whether it has cleared the neighborhood around it in its orbit

Elaborate:
Students research the history of the discovery of Ceres and Pluto.

Evaluate:
Assessments include the Venn diagram comparing planet, dwarf planet and asteroid and comet as found in the Explore activity worksheet. The worksheet includes a page of images to classify that can also be used as an assessment.

Cross-Curricular Link:
English Language Arts: In the Explore activity, students rewrite and compare definitions, both by writing and using graphic organizers to show the similarities and differences.

Day Four - Asteroids, Comets, and Meteoroids

Objective:
Students will differentiate between asteroids, comets, and meteoroids.

Next Generation Science Standards:
ESS1.A: The Universe and Its Stars
ESS1.B: Earth and the Solar System
PS2.A: Forces and Motion
CCC 3: Scale, Proportion, and Quantity
CCC 4: Systems and System Models
SEP 2: Developing and Using Models
SEP 3: Planning and Carrying Out Investigations
SEP 4: Analyzing and Interpreting Data
SEP 5: Using Mathematics and Computational Thinking

Common Core Standards:
CCSS.ELA-Literacy.RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
CCSS.Math.Practice.MP2: Reason abstractly and quantitatively.
CCSS.Math.Practice.MP4: Model with mathematics.
CCSS.Math.Practice.MP6: Attend to precision.

Materials:
Dry ice, dirt, dish liquid, quart-size baggie, two different colors of clay or play dough, balloons, flour, small pebbles, water, funnel, measuring cup, thin stick or skewer, graph paper, student worksheets

Engage:
Tell students that you received another mysterious note about the picture. This one says, "NASA wants to know more about Vesta - have you classified it?" Remind them of their findings from yesterday's investigation and ask if they are certain of Vesta's identity. Use the activity "Comets - A Physical Model" http://www.astro.virginia.edu/dsbk/resources.php as a teacher-performed demonstration. Tell students that comets are Solar System bodies that formed through accretion.

Explore:
To keep the suspense going, use *Exploring Meteorite Mysteries* http://ares.jsc.nasa.gov/ares/education/program/expmetmys.cfm Lesson 3, "Searching for Meteorites." This lesson helps students quantify data scientists learn from meteorite falls. Meteorites are important clues to the composition of asteroids.
OR
The activity "Modeling Asteroid Vesta in 3D" http://dawn.jpl.nasa.gov/DawnKids/SAYourMissionVesta3D.pdf gives students an opportunity to build a clay model to explore the possible explanations of the light and dark patches on the images of Vesta.

Explain:
Students copy vocabulary, definitions, and concepts into their Asteroid Journals
Vocabulary:
Vesta, Ceres, comet, ellipse, orbit, asteroid belt, meteor, meteoroid, meteorite

Concepts:

- Know the differences between comets and asteroids
- Understand how meteoroids get from the asteroid belt to Earth

Elaborate:
The interactive rock/meteorite identification website http://dawn.jpl.nasa.gov/Meteorite/index.asp features an interactive slide show that gives more information about asteroids and the DAWN mission.

Evaluate:
Assess student knowledge with the vocabulary quiz on terms from days one through three.

Cross-Curricular Link:
Art: Students can create an artistic and informative display for the 3D model of Vesta they made in the Explore activity.

Day Five - Observing Asteroids

Objective:
Students will use observations of light, heat, and metals, and then use that information to interpret the information that scientists collect about asteroids.

Next Generation Science Standards
For complete description of each standard, click on the links below.
*ESS1.B: Earth and the Solar System
*PS4.B: Electromagnetic Radiation
*CCC 5: Energy and Matter

Common Core Standards
*CCSS.ELA-Literacy.RST.6-8.3
*CCSS.ELA-Literacy.WHST.6-8.2
*CCSS.Math.Practice.MP4
*CCSS.Math.Practice.MP5
*CCSS.Math.Practice.MP7

Materials:
Metric rulers, calculators, pictures of asteroids, large nail or small piece of metal piping, metal file, white paper, 8 cm squares of construction paper (one each of red, black, blue, and white), thermometers, incandescent light source, 2 ring stands, clamps, cardboard, 50 cm square of non-shiny black paper or cloth, student worksheets

Engage:
Now that the students are certain that Vesta is an asteroid, remind them that NASA wants to know more about it. Have students list ways they could find out about Vesta's surface features and composition in their journals.
Use worksheet one of the "Asteroid Eros - Finding the Scale" activity to practice measuring asteroid features.

Explore:
Follow the directions for *Meteorite Mysteries*
http://ares.jsc.nasa.gov/ares/education/program/expmetmys.cfm Lesson 5, "Looking at Asteroids." Activities one and two are completed in lab groups. Activity three can also be completed in lab groups if there is enough equipment and time; otherwise it can be completed as an interactive teacher demonstration. The teacher can then set up the equipment and have students participate by coming forward, evaluating the reflectance of different colors, and taking temperature readings. Students record these observations on their data sheets.

Explain:
Students copy vocabulary, definitions, and concepts into their Asteroid Journals.
Vocabulary:
Reflectance, light, EM spectrum

Concepts:
- Scientists think that most meteorites are fragments of asteroids, though a few come from planets or other bodies like the Moon.

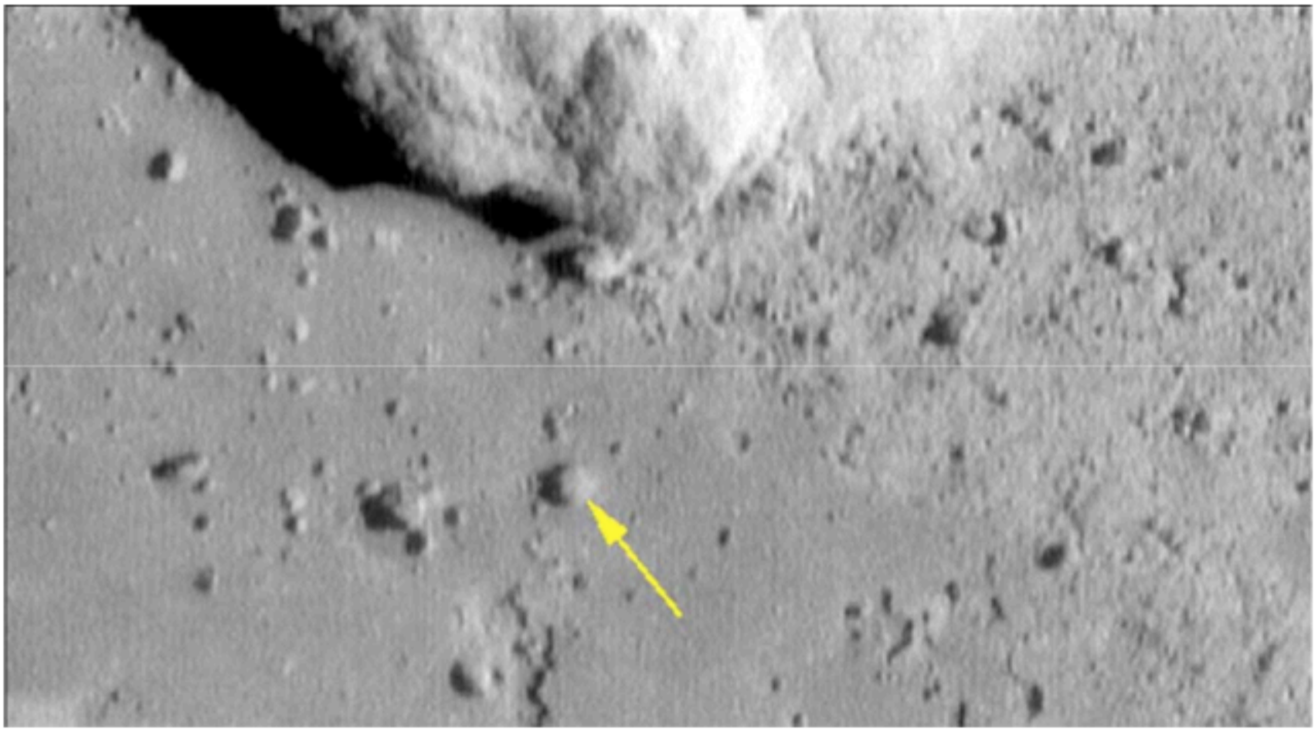
- Meteorites and asteroids are evaluated using brightness (reflectivity, as well as texture and color of materials.)

Elaborate:
Interactive asteroid games http://www.killerasteroids.org/
OR Vesta flipbook http://dawn.jpl.nasa.gov/dawnkids/SAYourMissionFlipbook.pdf OR Station 4 in *Meteorite Mysteries* Lesson 5, "Looking at Asteroids"

Evaluate:
The quiz on concepts for days one through four can be administered as an assessment tool, as well as the completed lab worksheets and completion of vocabulary in journals.

Cross-Curricular Link:
Math: Challenge questions for "Asteroid Eros - Finding the Scale" activity, worksheet 2

Asteroid Eros - Finding the Scale



This NASA, NEAR image of the surface of the asteroid Eros was taken on February 12, 2001 from an altitude of 120 meters. The image shows an area of the asteroid that is 6 meters wide. (Credit: Dr. Joseph Veverka/ NEAR Imaging Team/Cornell University)

The scale of an image is found by measuring with a ruler the distance between two points on the image whose separation in physical units you know. In this case, we are told the image width is 6.0 meters. We will use this information to calculate the scale of the picture.

Step 1: Measure the width of the image with a metric ruler. How many millimeters wide is the image?

Step 2: What does the caption say is the actual width of the asteroid's surface that is shown? What is the answer in centimeters?

Step 3: Divide your answer to Step 2 by your answer to Step 1 to get the image scale in centimeters per millimeter to two significant figures. This number is the *image scale.*

Once you know the image scale, you can measure the size of any feature in the image in millimeters. Then multiply it by the image scale from Step 3 to get the actual size of the feature in centimeters to two significant figures.

Asteroid Eros

Challenge Questions

Question 1:
What are the dimensions, in meters, of this image?

Question 2:
What is the width, in centimeters, of the largest feature?

Question 3:
What is the size of the smallest feature you can see?

Question 4:
How big is the stone shown by the arrow?

Asteroid Eros - Answer Key:

This NASA, NEAR image of the surface of the asteroid Eros was taken on February 12, 2001 from an altitude of 120 meters (Credit: Dr. Joseph Veverka/ NEAR Imaging Team/Cornell University)). The image is 6 meters wide.

The scale of an image is found by measuring with a ruler the distance between two points on the image whose separation in physical units you know. In this case, we are told the image width is 6 meters.

Please note that correct answers may be slightly different from what is here depending on document and printer settings!

Step 1: Measure the width of the image with a metric ruler. How many millimeters long is the image?
Answer: 144 millimeters

Step 2: Use clues in the image description to determine a physical distance or length.
Answer: 6.0 meters

Step 3: Divide your answer to Step 2 by your answer to Step 1 to get the image scale in centimeters per millimeter.
Answer: 6.0 meters / 144 mm = 600 cm / 144 millimeters = 4.2 cm/mm

Once you know the image scale, you can measure the size of any feature in the image in units of millimeters. Then multiply it by the image scale from Step 3 to get the actual size of the feature in centimeters.

Question 1: What are the dimensions, in meters, of this image?
Answer: Height = 80 mm = 336 cm or 3.4 meters so area is 6.0 m x 3.4 m

Question 2: What is the width, in centimeters, of the largest feature?
Answer: The big rock at the top of the image is about 60 mm across or 2.5 meters.

Question 3: What is the size of the smallest feature you can see?
Answer: The small pebbles are about 0.5 millimeters across or 2.1 centimeters (about 1 inch).

Question 4: How big is the stone shown by the arrow?
Answer: 4 millimeters or 17 centimeters (about 7 inches).

From NASA Space Math http://spacemath.gsfc.nasa.gov

Day Six - Asteroid Cratering

Objective:
Students will model the process of cratering in the Solar System and use this information to interpret impact crater features on asteroids.

Next Generation Science Standards:
For complete description of each standard, click on the links below.

*ESS1.B: Earth and the Solar System
*PS3.A: Definitions of Energy
*PS3.C: Relationship Between Energy and Forces
*PS3.B: Conservation of Energy and Energy Transfer
*CCC 2: Cause and Effect
*CCC 7: Stability and Change
*SEP 8: Obtaining, Evaluating, and Communicating Information

Common Core Standards:
CCSS.ELA-Literacy.RST.6-8.2
*CCSS.ELA-Literacy.RST.6-8.3
CCSS.ELA-Literacy.WHST.6-8.7

Materials:
Plaster of Paris, one large disposable pan or box (if completed as a class demo) or 3-4 small and deep containers such as margarine tubs or loaf pans (for groups), mixing container, stirring sticks, water, projectiles (e.g. pebbles, steel shot, lead fishing sinkers, ball bearings), powdered gelatin or cocoa or fine colored sand, strainer, meter stick, student lab and data sheets.

Engage:
Tell students that, in order to give a full report to NASA, they must be able to explain how the features on the surface of Vesta were formed. The work they do today will help them understand one of those types of features – impact craters.
Show one of the NASA videos of the human-made impact crater on Comet Tempel 1 at http://solarsystem.nasa.gov/deepimpact/gallery/animation.cfm

Explore:
Follow the directions for *Meteorite Mysteries* http://ares.jsc.nasa.gov/ares/education/program/expmetmys.cfm Lesson 6, "Impact Craters - Holes in the Ground," Activity A
Lead students in a discussion to explain their findings and point to evidence of craters on Vesta. Have them answer these questions in their journals: Are all of Vesta's craters circular? Why?

Explain:
Students copy vocabulary, definitions, and concepts into their Asteroid Journals.
Vocabulary:
crater, impact, projectile, velocity, ejecta, rim

Concepts:
- Impact craters are formed when pieces of asteroids or comets strike the surface of a planetary body.
- When an impact crater is formed, kinetic energy is transferred from the moving mass to the planetary body that it hits.

- Events that happen after an impact crater is formed can affect the shape of the crater.

Elaborate:
Meteorite Mysteries Lesson 7, "Crater Hunters"

Evaluate:
The completed data table and answers to questions in the day's activity are the assessments for this day.

Cross-Curricular Link:
Geography: Students research locations of craters on Earth.

Day Seven - Mapping

Objective:
Students will learn how to map craters at the *CosmoQuest* website "Vesta Mappers" and participate in a citizen science project.

Next Generation Science Standards
For complete description of each standard, click on the links below.

*ESS1.B: Earth and the Solar System
*CCC 1: Patterns
*SEP 4: Analyzing and Interpreting Data

Common Core Standards
*CCSS.ELA-Literacy.RST.6-8.4
*CCSS.ELA-Literacy.WHST.6-8.9

Materials:
Computer access for individual or pairs of students

Engage:
Tell the students that today is the day they really get to work for NASA! The *DAWN* mission that orbited Vesta collected thousands of images that have to be evaluated. In order to be able to quickly and accurately read and interpret the images, citizen scientists around the world are viewing them and marking the craters they find. Students will now become part of that group of scientists.
Introduce students to the *CosmoQuest* website http://www.cosmoquest.org, focusing on "Vesta Mappers."

Explore: Have students complete the tutorial and map crater images on Vesta.

Explain:
Lead a discussion of student findings. Ask them to show their favorite image and explain how they think the features were formed. Other students can be encouraged to agree or disagree, as long as they provide evidence for their ideas.

Elaborate:
The *DAWN* mission activity "Vegetable Light Curves" http://dawn.jpl.nasa.gov/DawnClassrooms/light_curves/ allows students to explore a three-dimensional model to interpret the differences in light and dark areas of asteroid images.

Evaluate:
Choose one image of Vesta to project for the whole class to see. Have students write an explanation of the cratering observed in one image, using supporting facts from their journals. Collect the journals and use as an assessment tool.

Cross-Curricular Link:
Social Studies/English Language Arts: Students can research and present the life of Kenneth Edgeworth or Gerard Kuiper.

Day Eight - Expedition Asteroid Part 1: Landing on Vesta

Objective:
Students will use engineering practices to design, build, and test a device that meets specifications for a vehicle that will land on a target. Students will compare engineering practices with science practices.

Next Generation Science Standards:
For complete description of each standard, click on the links below.

*CCC 6: [Structure and Function]
*[MS-ETS1-1] Define the criteria and constraints of a design problem
*[MS-ETS1-4] Develop a model to generate data for iterative testing
*SEP 1 [Asking Questions and Defining Problems]
*SEP 6: [Constructing Explanations and Designing Solutions]

Common Core Standards
*[CCSS.Math.Practice.MP6] Attend to precision.
*[CCSS.Math.Practice.MP7] Look for and make use of structure.
*[CCSS.ELA-Literacy.WHST.6-8.2] Write informative/explanatory texts

Materials:
Meter sticks, metric rulers or tape measures, target, (Draw two concentric rings in the center of a standard paper plate) paper cups, straws, tape, rubber bands, string, index cards, paper clips, and other appropriate building materials
(It is suggested that all teams receive the same number and type of materials. Teachers may want to prepare "kits" of materials in advance so they can easily be distributed to the students. Extra materials may be made available to students at a "charge" of one point per item.)
Pictures of various landers may be displayed to inspire student creativity.

Engage:
NASA is planning human expeditions to the moons of Jupiter, Saturn, Uranus, and Neptune to explore, collect samples, and search for clues to help us understand the formation of the Solar System. Since rocket fuel, water, food, and other essentials are heavy and bulky, it's impractical to transport them from Earth. Instead, NASA is looking for sources of rocket fuel and other consumables in the asteroid belt. Your team will design a prospecting expedition to the asteroid Vesta to look for resources that could be used for long distance space flights. Today you will be designing a space vehicle that can land on a target and remain upright.

Explore:
1. Divide the students into Engineering Teams of three to five students.
2. Give the students the specifications for their landing vehicles:
   - The lander must be no larger than a 20 cm cube.
   - The lander will be dropped from a height of one meter above a target.
   - The lander must land upright on the target.
3. Tell students how they will be scored:
   - Ten points will be awarded to teams who complete the task as specified and land in the center of the bull's-eye without bouncing.
   - Eight points will be awarded to teams who complete the task as specified and land in the second ring of the target without bouncing.

- Five points will be awarded to teams who complete the task to specifications but don't land on the target or flip over after landing.
- One point will be subtracted for each trial drop. One point will also be subtracted for each extra piece of material used beyond the basic materials provided to each team.

4. In their journals, students will record the results of each test. Discuss how they might record the following information:
   - Design plan for the lander (They may choose a sketch or narrative description)
   - Modifications made to the design after each attempt (Sketch or narrative)
   - Comments on the success of one attempt as compared to another
   - The distance from the center of the target to the place where their lander first touched the floor (Suggest a simple table of measurements.)
5. Give students the materials and allow them time to design their landers. Alternatively, a sketch of the planned design could be a requirement to receive the materials. Student teams should have most of the class period to build, test, and rebuild their landers.
6. Allow students to conduct their final test by dropping the lander on the target to score points.

Explain:
Students copy vocabulary, definitions, and concepts into their Asteroid Journals.
<u>Vocabulary:</u>
Design, analyze, interpret, model, investigation
<u>Concepts:</u>
Engineering design is similar to scientific experimentation

- Both have a problem or question to solve
- Both plan and carry out investigations to solve the problem or question
- Both use math to analyze and interpret data
- Both use evidence to communicate information

There are differences between science and engineering:

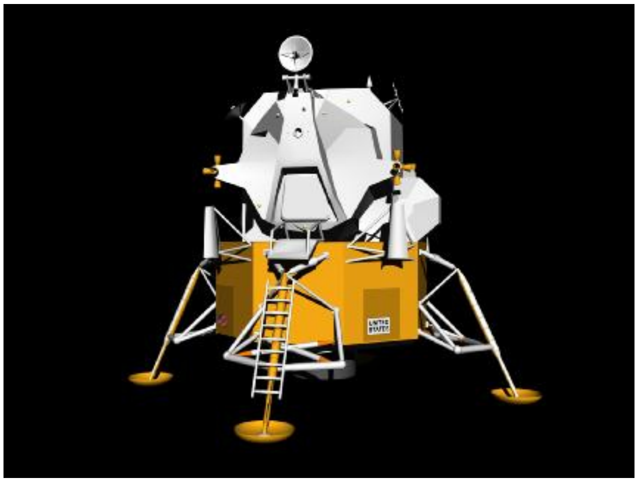
- The difference between science or engineering depends on the goal of the activity you're doing:
  - Is your goal to answer a question? If so, you're doing science.
  - Is your goal to define and solve a problem? If so, you're doing engineering.
- Engineering usually results in a physical product; experiments usually result in data that support a hypothesis

Elaborate:
Invite students to learn more about the GRaND asteroid probe at the interactive website at http://dawn.jpl.nasa.gov/technology/GRaND_inter.asp

Evaluate:
Assess student knowledge with the vocabulary quiz on terms from days four through seven. Use the Expedition Asteroid score sheet and students' journals to check their success in completing the task.

Cross-Curricular Link:
English Language Arts: Recording sketches, modifications, thoughts, and results in their journals will improve journaling skills.

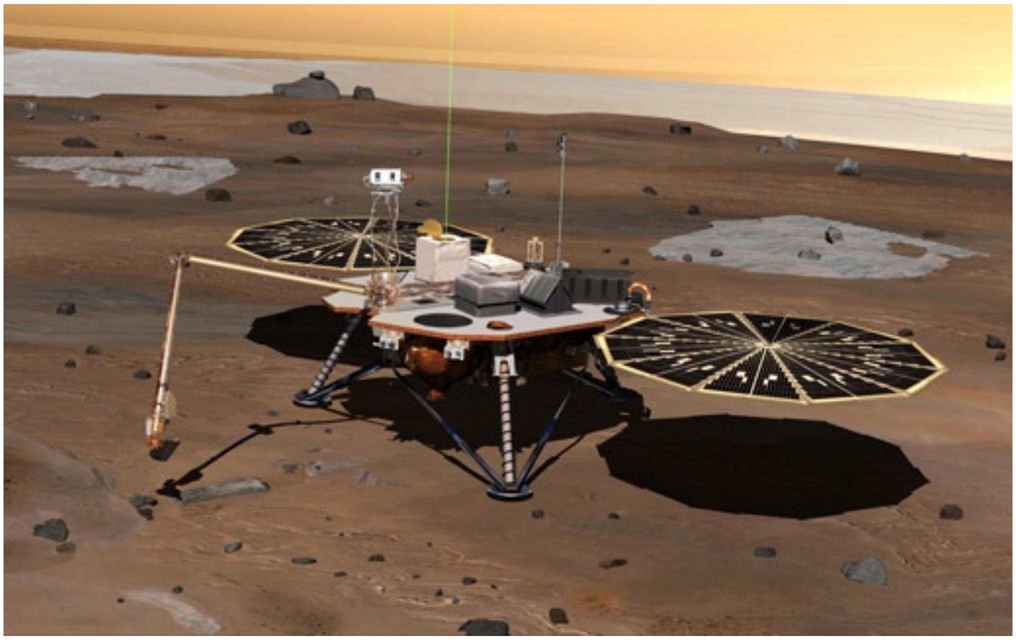
Landers 1



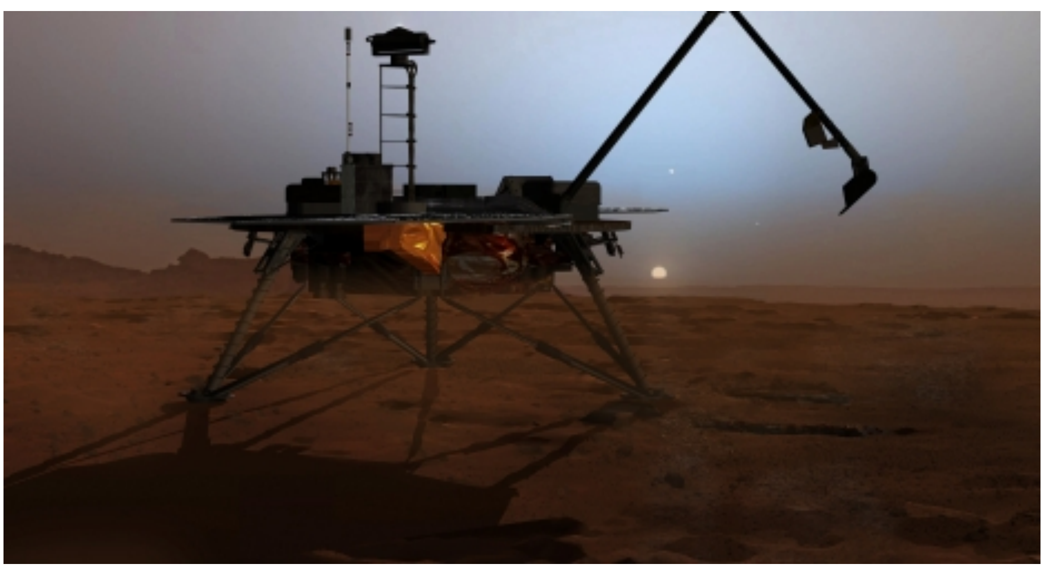
Apollo Lunar Lander

Robotic Lunar Lander

Landers 2

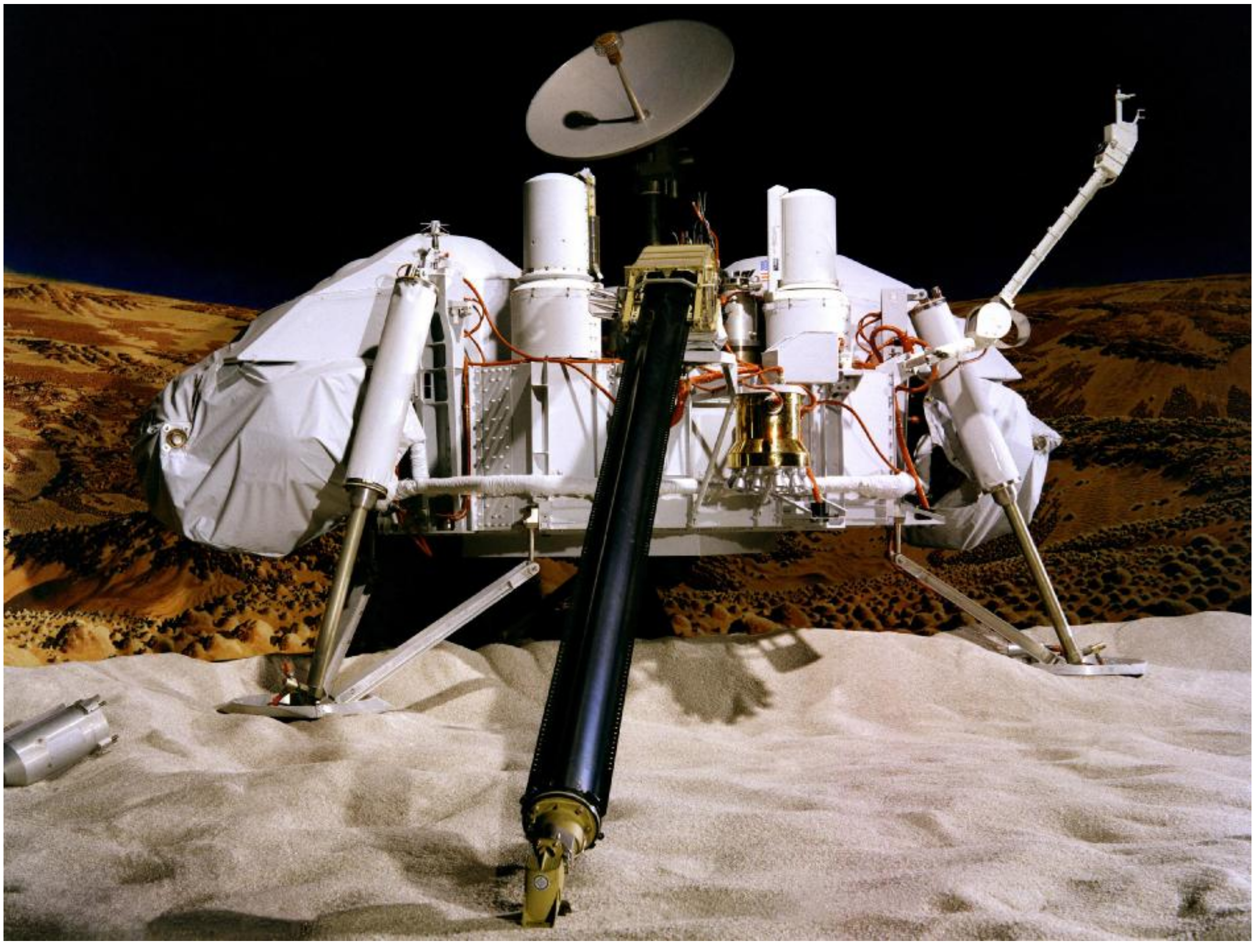


Mars Phoenix Lander



Mars Phoenix Lander

Landers 3



Mars Viking Lander

Expedition Asteroid: Landing on Vesta

Student Guide

TODAY:
Your team embarks on Expedition Asteroid, a prospecting mission to the asteroid Vesta.

GOAL:
To land you spacecraft on the asteroid so you can begin to explore the resources you can use for a future five-year trip to explore Jupiter's moon Io.

CHALLENGE:
Design a space vehicle that can land on a moving target and remain upright.

SPECIFICATIONS:
- The lander must be no larger than a 20 cm cube.
- The lander will be dropped from a height of one meter above a target.
- The lander must land upright on the target.

PROCEDURE:
- All notes, sketches, and plans should be included in your journal.
- With your team, design plan for a lander. Sketch your design
- Build your lander and conduct pre-tests to see how close your lander will come to a target.
- Measure the distance from your lander to the target for each test.
- Record the results of your tests.
- List the modifications made between tests
- Compare the success of one test to another.
- Include a results table that includes data from each trial, including the distance from the center of the target to the place where your lander first touches the floor.

POINTS:
- **10 points** will be awarded to teams who complete the task as specified and land in the center of the bull's-eye without bouncing.
- **8 points** will be awarded to teams who complete the task as specified and land in the second ring of the target without bouncing.
- **5 points** will be awarded to teams who complete the task to specifications but don't land on the target or flip over after landing.
- **1 point** will be subtracted for each trial drop. One point will also be subtracted for each extra piece of material used beyond the basic materials provided to each team to build the lander.

Expedition Asteroid Report Form

	Points Added	Points Deducted	Total Points
Vesta Landing			
Proximity to target 10 points land in center 8 points outer ring 5 points on asteroid			
Lands upright 10 points upright			
Number of attempts Deduct one point for each attempt			
Materials used Deduct one point for each extra piece of material used			
Mining Vesta			
Matter in sorter 10 points for any material in any of the containers			
Matter sorted 1 point per gram of mass in correct container			
Number of attempts Deduct one point for each attempt			
Materials used Deduct one point for each extra piece of material used			
Vesta Landing			
Proximity to target 10 points land in center 8 points outer ring 5 points on asteroid			
Lands upright 10 points upright			
Number of attempts Deduct one point for each attempt			
Materials used Deduct one point for each extra piece of material used			
TOTAL POINTS			

Day Nine - Expedition Asteroid Part 2: Mining Vesta

Objective:
Students will use engineering practices to design, build, and test a device that meets specifications for a device that will separate a mixture of materials into their component parts. Students will identify the natural resources found on asteroids that are important for space travel.

Next Generation Science Standards:
For complete description of each standard, click on the links below.

*ESS1.B: Earth and the Solar System
*CCC 6: Structure and Function
*MS-ETS1-1 Define the criteria and constraints of a design problem
*MS-ETS1-4 Develop a model to generate data for iterative testing
*SEP 1 Asking Questions and Defining Problems
*SEP 6: Constructing Explanations and Designing Solutions

Common Core Standards
*CCSS.Math.Practice.MP6 Attend to precision.
*CCSS.Math.Practice.MP7 Look for and make use of structure.
*CCSS.ELA-Literacy.WHST.6-8.2 Write informative/explanatory texts

Materials:
Per team:
One paper cup that contains 10 small paperclips, 10 plastic beads (5 mm diameter or larger), and about 25 ml of clean sand
3 paper cups to collect sorted materials (labeled "sand," "beads," and "clips")
Building materials such as index cards, tape, magnets, string, straws, construction paper and rubber bands (It is suggested that all teams receive the same number and type of materials. Teachers may want to prepare "kits" of materials in advance so they can easily be distributed to the students. Extra materials may be made available to students at a "charge" of one point per item.)
Electronic or triple beam balance to measure the mass of materials sorted

Engage:
Hold up a clear beaker of sand, plastic beads and paperclips. Ask the students, "How would you separate the items in this beaker?" After they offer a few suggestions, ask "How would you do it without touching the materials?" Allow students to brainstorm possible solutions. Remind students that Vesta has different resources that would have to be separated as part of the mining process. Engineers must develop ways to efficiently sort mined materials.

Explore:
Design a device to separate the given mixture into three different containers.
In their journals, students record the results of each test, including the amount or mass of the material correctly sorted during each attempt, modifications made to the design, and comments on the success of one attempt as compared to another.

1. Students continue to work with their Engineering Teams from the previous day.
2. Give the students the specifications for their sorter:
    - The sorter must be no larger than a 50 cm cube.
    - The mixture will be poured into the sorter at some type of receiving container as indicated by the team.

- The sorter must then automatically separate the sand, beads, and paper clips into the three labeled containers: sand must go in the container labeled “sand,” beads in the containers labeled “beads,” etc.

3. Tell students how they will be scored:
   - Ten points will be awarded to teams who complete the task as specified and end the task with any of the materials getting to any of the containers.
   - 1 point per gram of mass will be awarded to teams who complete the task as specified and ended the task with the correct matter in the correct container.
   - One point will be subtracted for each trial attempted and each time a team member touches the sorter during the sorting process. One point will also be subtracted for each extra piece of material used beyond the basic materials provided to each team.

4. In their journals, students will record the results of each test. Discuss how they might record the following information:
   - Design plan for the sorter (They may choose a sketch or narrative description)
   - Modifications made to the design after each attempt (Sketch or narrative)
   - Comments on the success of one attempt as compared to another
   - The mass of each material that was successfully sorted into the correct container (Suggest a simple table of measurements.)

5. Give students the materials and allow them time to design their sorters. Alternatively, a sketch of the planned design could be a requirement to receive the materials. Student teams should have most of the class period to build, test, and rebuild their sorters.

6. Allow students to conduct their final test by pouring the mixture into the sorter to score points.

Explain:

Students copy vocabulary, definitions, and concepts into their Asteroid Journals.

<u>Vocabulary:</u>

Prospector, metals, volatiles, carbonaceous chondrite, ureilites

<u>Concepts:</u>

Two types of materials on asteroids are metals and volatiles, which are essential for space travel. Materials that are already in space can be very valuable for deep space expeditions. It has been proposed that mines and manufacturing plants on asteroids would be able to supply materials for deep space expeditions.

- Metals: An asteroid of the composition of an ordinary chondrite could be processed to provide very pure iron and nickel. Valuable byproducts would include cobalt, platinum, gallium, germanium, and gold. These metals are basic to the production of steel and electronic equipment. Some metals from an asteroid mine might even prove valuable enough to be returned to Earth. Iron meteorites are high-grade ores. Diamonds or platinum may be found and have both monetary and industrial value. In addition, fine surface materials similar to soils may be suitable for nutrient or plant growth material, insulation, or building materials.
- Volatiles: Water, oxygen, and carbon compounds are useful in any space settlement, both for life support and for producing rocket fuel. These volatiles could be found in an asteroid that resembles a carbonaceous chondrite or the nucleus of a former comet. Water contents may range from 5-10% by weight for a chondrite to 60% by weight for a comet nucleus. In some asteroids large quantities of sulfur, chlorine and nitrogen may also be available.

Evaluate:
Use the Expedition Asteroid score sheet and students' journals to check their success in completing the task.

Elaborate:
Challenge students to brainstorm the adjustments that would be necessary for the sorter to work in a microgravity environment and then sketch a drawing of their designs.

Cross-curricular Link:
Social studies: compare and contrast mining challenges on Earth with those in space

Expedition Asteroid: Mining Vesta

Student Guide

TODAY:
Now that you're mining on Vesta, how do you separate valuable resources from the rest of the rock you've mined?

GOAL:
To separate the resources you've mined to allow you to refine and transport them.

CHALLENGE:
Develop a way to efficiently sort materials into separate containers.

SPECIFICATIONS:

- The sorter must be no larger than a 50 cm cube.
- The mixture will be poured into the sorter at some type of receiving container as indicated by the team.
- The sorter must then automatically separate the sand, beads, and paper clips into the three labeled containers: sand must go in the container labeled "sand," beads in the containers labeled "beads," etc.

PROCEDURE:

- All notes, sketches, and plans should be included in your journal.
- With your team, design a plan for a sorter. Sketch your design.
- Build your sorter and conduct pre-tests to see how well materials move to each collecting container.
- Measure the mass of sorted material for each test.
- Record the results of your tests.
- List the modifications made between tests.
- Compare the success of one test to another.
- Include a results table that includes data from each trial, including the distance from the center of the target to the place where your lander first touches the floor.

POINTS:

- **10 points** will be awarded to teams who complete the task as specified and end the task with any of the materials getting to any of the collecting containers.
- **1 point** per gram of mass will be awarded to teams who complete the task as specified and end the task with the correct matter in the correct container.
- **1 point** will be subtracted for each trial attempted and each time a team member touches the sorter during the sorting process. One point will also be subtracted for each extra piece of material used beyond the basic materials provided to each team.

Day Ten - Expedition Asteroid Part 3: We Deliver!

Objective:
Students will use engineering practices to design, build, and test a device that delivers a payload to a target.
Students will list the possible benefits and possible impacts of mining an asteroid.

Next Generation Science Standards
For complete description of each standard, click on the links below.

CCC 6: Structure and Function
MS-ETS1-2 Evaluate competing design solutions
MS-ETS1-3 Analyze data from tests
MS-ETS1-4 Develop a model to generate data for iterative testing
SEP 1 Asking Questions and Defining Problems
SEP 5 Using Mathematics and Computational Thinking
SEP 6 Constructing Explanations and Designing Solutions

Common Core Standards
CCSS.Math.Practice.MP6 Attend to precision.
CCSS.Math.Practice.MP7 Look for and make use of structure.
CCSS.Math.Practice.MP8 Look for and express regularity in repeated reasoning.
CCSS.ELA-Literacy.WHST.6-8.1 Write arguments focused on *discipline-specific content*.
CCSS.ELA-Literacy.WHST.6-8.2 Write informative/explanatory texts.

Materials:
Meter sticks, metric rulers or tape measures, target, (Draw two concentric rings in the center of a standard paper plate) paper cups, straws, tape, rubber bands, string, index cards, paper clips, and other appropriate building materials
(It is suggested that all teams receive the same number and type of materials. Teachers may want to prepare "kits" of materials in advance so they can easily be distributed to the students. Extra materials may be made available to students at a "charge" of one point per item.)
Pictures of various landers may be displayed to inspire student creativity.

Engage:
Now that you have collected resources from Vesta, we need to transport them to a space vehicle, either to take them back to Earth or to fuel an expedition to the outer Solar System.

Explore:
If necessary, students can use part of this class to complete the sorting activity from the previous day. When students are ready, they will repeat the launch activity from day eight, but this time they must fill their lander with the paper clips they sorted in the *Mining Vesta* activity and land it on the target without spilling any of the clips.

1. Students continue to work with their Engineering Teams.
2. Remind the students of the specifications for their landing vehicles:
   - The lander must be no larger than a 20 cm cube.
   - The lander will be dropped from a height of one meter above a target.
   - The lander must land upright on the target.
   - Paperclip payload must remain inside the lander.

3. Tell students how they will be scored:

- Ten points will be awarded to teams who complete the task as specified and land in the center of the bull's-eye without bouncing or losing any of the paperclip payload.
- Eight points will be awarded to teams who complete the task as specified and land in the second ring of the target without bouncing or losing any of the paperclip payload.
- Five points will be awarded to teams who complete the task to specifications but don't land on the target or flip over after landing or lose paperclips from the lander.
- One point will be subtracted for each trial drop. One point will also be subtracted for each extra piece of material used to build the lander.

4. In their journals, students will record the results of each test. Discuss how they might record the following information:
   - Design a plan for adapting the lander (They may choose a sketch or narrative description)
   - Modifications made to the design after each attempt (Sketch or narrative)
   - Comments on the success of one attempt as compared to another
   - The distance from the center of the target to the place where their lander first touched the floor (Suggest a simple table of measurements.)
5. Give students the materials and allow them time to redesign their landers. Alternatively, a sketch of the planned design could be a requirement to receive the materials. Student teams should have most of the class period to redesign, test, and rebuild their landers.
6. Allow students to conduct their final test by dropping the lander on the target to score points.

In their journals, students record the results of each test, including the distance from the center of the target to the place where their lander first touched the floor, modifications made to the design, and comments on the success of one attempt as compared to another.

Explain:

Students copy vocabulary, definitions, and concepts into their Asteroid Journals.

<u>Vocabulary:</u>

Cost benefit analysis, impact

<u>Concepts:</u>

- Any mining activity has an impact on the area being mined.
- Sometimes the impacts are not easy to see, or take months or years to become evident.
- Careful research must be conducted to choose the method that has the least impact on the mining environment while still maintaining a high yield of resources.
- Companies involved in mining and other activities conduct a **cost benefit analysis** to see if the amount of resources gained is worth the cost of mining them.

Elaborate:

Challenge students to list the possible impacts of mining activity on an asteroid. Point out that changing the surface of the asteroid should be considered, as well as the effects of material floating away from the asteroid's low gravity environment.

Evaluate:

Use the Expedition Asteroid score sheet and students' journals to check their success in completing the task.

Cross-Curricular Link:

Mathematics: using the points they earned or deducted on their score sheets as dollars, students calculate the cost-effectiveness of their expeditions and compare their findings with other teams.

Expedition Asteroid: We Deliver!

Student Guide

TODAY:

Now that you have collected resources from Vesta, we need to transport them to a space vehicle, either to take then back to Earth or to fuel an expedition to the outer Solar System.

GOAL:

To land you spacecraft on the asteroid so you can begin to explore the resources you can use for a future five-year trip to explore Jupiter's moon Io.

CHALLENGE:

Design a space vehicle that can land on a moving target and remain upright.

SPECIFICATIONS:

- The lander must be no larger than a 20 cm cube.
- The lander will be dropped from a height of one meter above a target.
- The lander must land upright on the target.
- The paperclip payload must remain inside the lander.

PROCEDURE:

- All notes, sketches, and plans should be included in your journal.
- With your team, design a plan for a lander. Sketch your design.
- Build your lander and conduct pre-tests to see how close your lander will come to a target.
- Measure the distance from your lander to the target for each test.
- Record the results of your tests.
- List the modifications made between tests.
- Compare the success of one test to another.
- Include a results table that includes data from each trial, including the distance from the center of the target to the place where your lander first touches the floor.

POINTS:

- **10 points** will be awarded to teams who complete the task as specified and land in the center of the bull's-eye without bouncing or losing any of the paperclip payload.
- **8 points** will be awarded to teams who complete the task as specified and land in the second ring of the target without bouncing or losing any of the paperclip payload.
- **5 points** will be awarded to teams who complete the task to specifications but don't land on the target or flip over after landing or lose paperclips from the lander.
- **1 point** will be subtracted for each trial drop. One point will also be subtracted for each extra piece of material used beyond the basic materials provided to each team to build the lander.

Day Eleven - The Universe is Out to Get You

Objective:
Students will learn how meteorites get to Earth from the asteroid belt and how rare it is for Earth to be hit by a large asteroid. They will observe relative distances and sizes within the inner Solar System and gain an appreciation of the large amount of empty space in the Solar System.

Next Generation Science Standards
For complete description of each standard, click on the links below.

ESS1.B: Earth and the Solar System
ESS1.C: The History of Planet Earth
ESS3.B: Natural Hazards
CCC 3 Scale, Proportion, and Quantity
CCC 7 Stability and Change
SEP 8 Obtaining, Evaluating, and Communicating Information

Common Core Standards
RST.6-8.1Cite specific textual evidence to support analysis of science and technical texts.
WHST.6-8.7Conduct short research projects to answer a question
WHST.6-8.8Gather relevant information from multiple print and digital sources
MP.2Reason abstractly and quantitatively.

Materials:
Activity B: 1.2 meter square of stiff poster board or corrugated cardboard, 60x30 cm piece of stiff poster board or corrugated cardboard, pushpins, colored and regular pencils, string, scissors, ruler, protractor, clay dough in yellow or white, magazine with colored pictures; Activity C: paper (60 cm square), pencil an colored pencils, ruler, protractor, table #4

Engage:
Tell students that an asteroid is detected just hours before impacting the Earth. Scientists predicted that the object would impact Chicago in about 19 hours. Ask them to write in their journals what they think NASA should tell the public about the impending impact and what they think citizens should do to prepare. Then show and discuss the "TC3 Impact" power point http://dps.aas.org/files/dps/education/dpsdisc/2009/TC3Impact.ppt.

Explore:
Follow the directions for Meteorite Mysteries http://ares.jsc.nasa.gov/ares/education/program/expmetmys.cfm 4: Meteorite Asteroid Connection (Choose either B. Long road to Earth, or C. Collision Course)

Explain:
Students copy vocabulary, definitions, and concepts into their Asteroid Journals.
Vocabulary:
- Ellipse, orbit, asteroid, asteroid belt, ecliptic plane, retrograde, eccentricity of orbit

Concepts:
- The Solar System is mostly empty space.
- Many asteroids are in a belt between Mars and Jupiter.
- It is rare for Earth to be hit by a large asteroid because such asteroids are rare and because of the huge distances involved.

Elaborate:
Finding impact craters with LANDSAT at http://craters.gsfc.nasa.gov/index.htm
OR
Meteorite Mysteries http://ares.jsc.nasa.gov/ares/education/program/expmetmys.cfm 4: Meteorite Asteroid Connection Activity A, Finding orbits

Evaluate:
Assess student worksheets

Cross-Curricular Link:
Current events: Research meteors and asteroids in the news
English Language Arts: Evaluate news articles about meteor strikes for scientific accuracy

Student Worksheet
Name ____________
Date _____________

The Long and Winding Road to Earth

Adapted from "The Meteorite-Asteroid Connection" in NASA's Exploring Meteorite Mysteries

Objective:

- To construct a scale model of the inner Solar System including: the Sun, the inner planets, the asteroid belt, and the orbits of a few selected asteroids.
- To construct circular and elliptical planetary orbits
- To observe relative distances and sizes within the Solar System
- To plot the path meteoroids might take in traveling from the asteroid belt to Earth.
- To observe that the Earth is a small target.

Materials:

- 1.2 meter square (or larger) piece of corrugated cardboard or stiff poster board
- Pushpins, two per group
- Colored and regular pencils
- String, or loops of string in the lengths indicated in Table 1
- Scissors, ruler and protractor
- Clay-dough in yellow or white
- Magazine with colored pictures

Procedure:

1. Prepare your cardboard by marking the center; this will be the Sun's location.
2. Draw a circle 1.8-2 mm in diameter around this point; this is the scaled diameter of the Sun. Then, using a pencil, draw a light reference line from the Sun's center toward the side of the board.
3. Prepare the strings for each orbit using the string lengths in Table 1. Measure, cut, and carefully tape the ends so that they just touch. You will have a loop for each orbit.
4. Secure the string to the board using a glue stick. Check **Table 1** (below) to see which planetary bodies follow a circular orbit and which ones need an elliptical orbit. Two pins mean an elliptical and one pin means that planet has a circular orbit.
5. Label each orbit, as well as the asteroid belt.
6. Now it is time to add the Sun and planets to your model. You need to add the Sun and planets at the same scale as their orbits. **Table 2** (below) provides you with real and to-scale diameters. For example, at this scale the Sun should be a ball just under 2 mm in diameter, about the size of a BB. Use a metric ruler and clay-dough to fashion a representation of the Sun.
7. The Earth and Venus should be 1/50 mm across, which is almost invisible, smaller than a grain of salt or pinprick in paper, and about the thickness of standard copier paper. If you

look at a picture in a magazine with a 5 or 10X magnifying glasses, you will see individual dots. These dots are about three times too large, but will give you an idea of the correct scale. As best you can, make tiny dots to represent the Earth and Venus.

8. The Moon, Mercury, Mars and the asteroids are too small to be visible at this scale!

Table 1. Drawing Orbits in Scale Model

Orbit	Loop Circumference (knot to knot)	# pins	Pin 2 from Sun Distance	Pin 2 from Sun Angle
Mercury	18 cm	2	3.1 cm	270°
Venus	27 cm	1	--	--
Earth	39 cm	1	--	--
Mars	64 cm	2	5.6 cm	45°
Asteroid Belt: Inner Edge	84 cm	1	--	--
Asteroid Belt: Outer Edge	122 cm	1	--	--
Asteroid Ceres	114 cm	2	8.4 cm	78°
Asteroid 1983RD	118 cm	2	39 cm	173°
Asteroid Icarus	85 cm	2	38 cm	330°

Note: Asteroid 1983RD is now known as 3551 Verenia, and its spectrum indicates that it has a similar composition to Vesta.

Table 2. Real and Scaled Diameters of Solar System Objects

Object	Real Diameter	Scaled Diameter
Sun	1,400,000 km	1.8 mm
Mercury	4,880 km	1/150 mm
Venus	12,100 km	~1/50 mm
Earth	12,800 km	~1/50 mm
Moon	3,480 km	1/200 mm
Mars	6,800 km	~1/100 mm
Ceres	940 km	~1/1000 mm
1983RD	0.8 km	~1x10^{-6} mm
Icarus	0.9 km	~1x10^{-6} mm

Questions:

1. As you constructed your scale model of the inner planets and asteroid belt, what did you notice about the relative distances between astronomical bodies within the inner system?

2. What did you notice about the relative sizes of the astronomical bodies in the inner Solar System?

3. Where is the asteroid belt located?

4. Does the Solar System appear crowded or is there mostly open space?

5. Looking a the size of the Earth on your model and considering that it is a moving target, what do you think are the chances of the Earth being hit by large asteroids or comets? Give a reason for your answer.

Student Worksheet
Name ____________
Date _____________

Collision Course

Objective:

- To graph the locations of the Earth and a near-Earth asteroid.
- To observe from the graph that both time and location in space are important.
- To estimate when an asteroid would cross the Earth's orbit.
- To determine if a collision would take place.

Materials:

- Paper- approximately 60 cm x 60 cm
- Pencil and colored pencils (optional)
- Ruler
- Protractor
- Table 4

Procedure:

1. Mark the Sun point in the center of the paper. Use a pencil to draw a line from the Sun extending 30 cm in any direction. This will be the reference line from which angles are measured (see diagram).
2. Graph the orbit of the **Earth** and one **asteroid** on the paper. To draw an orbit from the numbers in **Table 4** (see below), begin with a single time at the left in Table 4. On that time in the Table, read the angle and distance for that time in orbit.
3. On the paper, use a protractor to measure the angle (clockwise) from the Sun and the reference line, and draw a line at that angle. Measure outward along that line to the distance listed in the table, and draw a dot at that distance (color-coded perhaps). Label the mark with month and half month.
4. After all the points are graphed and labeled, connect them freehand to make a smooth curve. The points may not make a full orbit.
5. Estimate when (month number and a fraction), that the asteroid crosses the Earth's orbit.
6. Measure the closest approach between the asteroid and the Earth by measuring the distances between corresponding time steps in their orbits.
7. Compare data with other lab groups. Determine which asteroid comes closest to hitting the Earth and how close it comes. (The scale here is 1 cm = 10,000,000 kilometers. The Earth (to scale) would be 1/100 mm).

Table 4. Distances from Sun and Angles from Reference Line for Earth and Asteroids

	Earth		Asteroid 1		Asteroid 2		Asteroid 3		Asteroid 4		Asteroid 5		Asteroid 6	
Month	**Dist**	**Angle**	**Dist**	**Angle**	**Dist**	**Angle**	**Dist**	**Angle**	**Dist**	**Angle**	**Dist**	**Angel**	**Dist**	**Angle**
0	15 cm	0°	8.4 cm	0°	23.7 cm	322°	30.6 cm	195°	55.4 cm	50°	23.6 cm	56°	51.1 cm	261°
1	15 cm	30°	10.8 cm	72°	23.5 cm	333°	27.0 cm	205°	53.9 cm	48°	21.4 cm	71°	49.5 cm	264°
2	15 cm	60°	14.8 cm	110°	22.6 cm	344°	23.1 cm	218°	52.1 cm	46°	19.0 cm	90°	47.7 cm	267°
3	15 cm	90°	18.2 cm	133°	20.8 cm	356°	19.2 cm	236°	50.1 cm	44°	16.7 cm	115°	45.6 cm	270°
4	15 cm	120°	20.7 cm	149°	18.2 cm	11°	15.6 cm	263°	47.7 cm	42°	15.0 cm	146°	43.2 cm	273°
5	15 cm	150°	22.4 cm	162°	14.7 cm	30°	13.4 cm	303°	45.1 cm	40°	14.6 cm	182°	40.4 cm	277°
6	15 cm	180°	23.3 cm	174°	10.8 cm	59°	14.1 cm	347°	42.0 cm	37°	15.5 cm	216°	37.4 cm	282°
7	15 cm	210°	23.3 cm	185°	8.6 cm	113°	17.2 cm	21°	38.6 cm	33°	17.5 cm	245°	33.9 cm	288°
8	15 cm	240°	22.5 cm	197°	11.1 cm	192°	21.0 cm	43°	34.7 cm	29°	19.9 cm	276°	30.1 cm	294°
9	15 cm	270°	20.9 cm	210°	15.0 cm	244°	25.0 cm	59°	30.3 cm	24°	22.2 cm	285°	25.8 cm	303°
10	15 cm	300°	18.5 cm	225°	18.4 cm	272°	28.8 cm	70°	25.2 cm	17°	24.4 cm	299°	20.9 cm	316°
11	15 cm	330°	15.2 cm	247°	20.9 cm	290°	32.2 cm	79°	19.1 cm	6°	26.2 cm	311°	15.6 cm	338°
12	15 cm	0°	11.2 cm	283°	22.7 cm	304°	35.4 cm	86°	11.9 cm	342°	27.7 cm	321°	10.7 cm	21°
13	15 cm	30°	8.5 cm	352°	23.6 cm	317°	38.3 cm	92°	5.4 cm	240°	28.8 cm	331°	10.0 cm	94°

Asteroid 1 = Castalia, (0 month is 1.5 months after perihelion at 0°)
Asteroid 2 = Cerebrus, (oriented so perihelion is on-line with Earth and Sun)
Asteroid 3 = Antinous, (starting 71 half-months after perihelion)
Asteroid 4 = Hephiastos, (starting at perihelion, but turned to retrograde orbit)
Asteroid 5 = Nereus, (arranged for a near-miss)
Asteroid 6 = Oljato, (starting at 51 half-months after perihelion, angle advanced by 85°)

Questions:

1. When did the asteroid that you chose to graph cross the Earth's orbit?

____

____

2. What was the closest approach between your asteroid and the Earth?

____

____

3. Which asteroid came closest to hitting the Earth and how close did it get?

____

____

4. What do you think the chances are of an asteroid hitting the Earth? Explain your answer.

____

____

____

____

Day Twelve - Review

Objective:
Students will review concepts and vocabulary introduced in the unit.

Standards:
All Next Generation Science Standards and Common Core Standards included in the unit.

Materials:
Student journals, review game of choice

Engage:
Preview the material that will be covered in the test, highlighting the format of the test, i.e. multiple choice only, lab practical, etc.

Explore:
None

Explain:
Explain concepts as necessary. It is suggested that a game format such as Trivial Pursuit, Jeopardy, etc. be used to keep the students engaged throughout the review.

Elaborate:
None

Evaluate:
Informally assess student knowledge during review game

Interdisciplinary Link:
None

Day Thirteen - Assessment

Objective:
Final assessment of student knowledge

Standards:
All Next Generation Science Standards and Common Core Standards included in the unit.

Materials:
Paper, pencil, test

Engage:
Prepare students for test, as necessary.

Explore:
None

Explain:
None

Elaborate:
None

Evaluate:
Administer posttest

Interdisciplinary Link:
None

Appendix A – Assessment

Name ________________________
Date _________________________

InVESTAgate Pre-Test

Match the following words with their definition:

1. ______ Astronomer
2. ______ Prospector
3. ______ Accretion
4. ______ Crater
5. ______ Planet
6. ______ Vesta

7. ______ Sphere
8. ______ Impact
9. ______ Orbit

10. ______ Meteorite
11. ______ Ejecta
12. ______ Mass

13. ______ Ellipse
14. ______ Reflectance
15. ______ Chondrite

A. Stony meteorite containing chondrules embedded in a fine matrix of pyroxene, olivine, and metallic nickel-iron
B. One who studies the science of celestial bodies
C. A closed curve of oval shape
D. Material thrown out from and deposited around impact craters
E. One of the largest asteroids in the Solar System
F. The amount of light of a particular color reflected by a surface
G. Any of the eight large celestial bodies revolving around the Sun
H. One who explores an area for minerals and other materials
I. Accumulation under the influence of gravity and some minor forces
J. The amount of matter in an object
K. An object that is round or almost round
L. A hole or depression
M. The forceful striking of one body against another such as a moon or planet
N. The path of an object in space moving around another
O. A metallic or stony body that has fallen on the Earth, Moon, or other planetary body

Write the words true or false in the blank.

16. __________ Gravity is related to movement, nearness of Earth, or magnetic fields.
17. __________ The Moon has no gravity.
18. __________ Gravity is a force.
19. __________ Planets far away from the Sun have less gravity.
20. __________ Gravity keeps the planets in orbit around the Sun.

Short Answer

21. If a baseball and a wad of paper the same size as the ball are dropped in a vacuum from the same height and at the same time, which one will land first? Explain your answer.

    ____

    ____

    ____

    ____

22. Where in the Solar System are most asteroids located?

    ____

    ____

23. What is the difference between an asteroid, planet, and dwarf planet?

    ____

    ____

    ____

    ____

24. What is the difference between an asteroid and meteoroid?

    ____

    ____

    ____

25. What are the chances of the Earth being hit by a meteoroid? Explain your answer.

    ____

    ____

    ____

    ____

InVESTAgate Pre-Test Answer Key

1. B
2. H
3. I
4. L
5. G
6. E
7. K
8. M
9. N
10. O
11. D
12. J
13. C
14. F
15. A
16. False
17. False
18. True
19. False
20. True
21. They would land at the same time because the force of gravity on them is the same.
22. The asteroid belt is located between Mars and Jupiter.
23. An asteroid orbits the Sun inside the orbit of Jupiter, is not round shaped, is not a satellite, and has not cleared the neighborhood around its orbit of most bodies. A planet is a celestial body that orbits the Sun, is nearly round, is not a satellite, and has cleared the neighborhood around its orbit of most bodies. A dwarf planet is in orbit around the Sun, is nearly round, is not a satellite, and has not cleared the neighborhood around its orbit.
24. Asteroids are smaller than planets, usually located in the belt between Mars and Jupiter, and, in general, are rocky bodies with no atmosphere. Some have high metallic content. Meteoroids are interplanetary objects that are smaller than asteroids. When they enter the atmosphere of another object, they often vaporize. If they survive to impact the surface, they are called meteorites.
25. Meteoroids can and have impacted the Earth, as evidenced by impact craters found in several places on Earth. However, because the Solar System is mostly empty space, it is rare for the Earth to be hit by one.

Name ________________
Date _________________

Vesta Concept Quiz

1. How do planetary bodies build and what is this called?

____
____
____

2. List two things that you know about gravity?

____
____
____

3. What is the difference between the gravity and mass of an object?

____
____
____

4. On the back of the paper, make a Venn diagram comparing an asteroid, planet, and dwarf planet.

5. Why are meteorites difficult to find on the surface of the Earth?

____
____
____
____
____
____

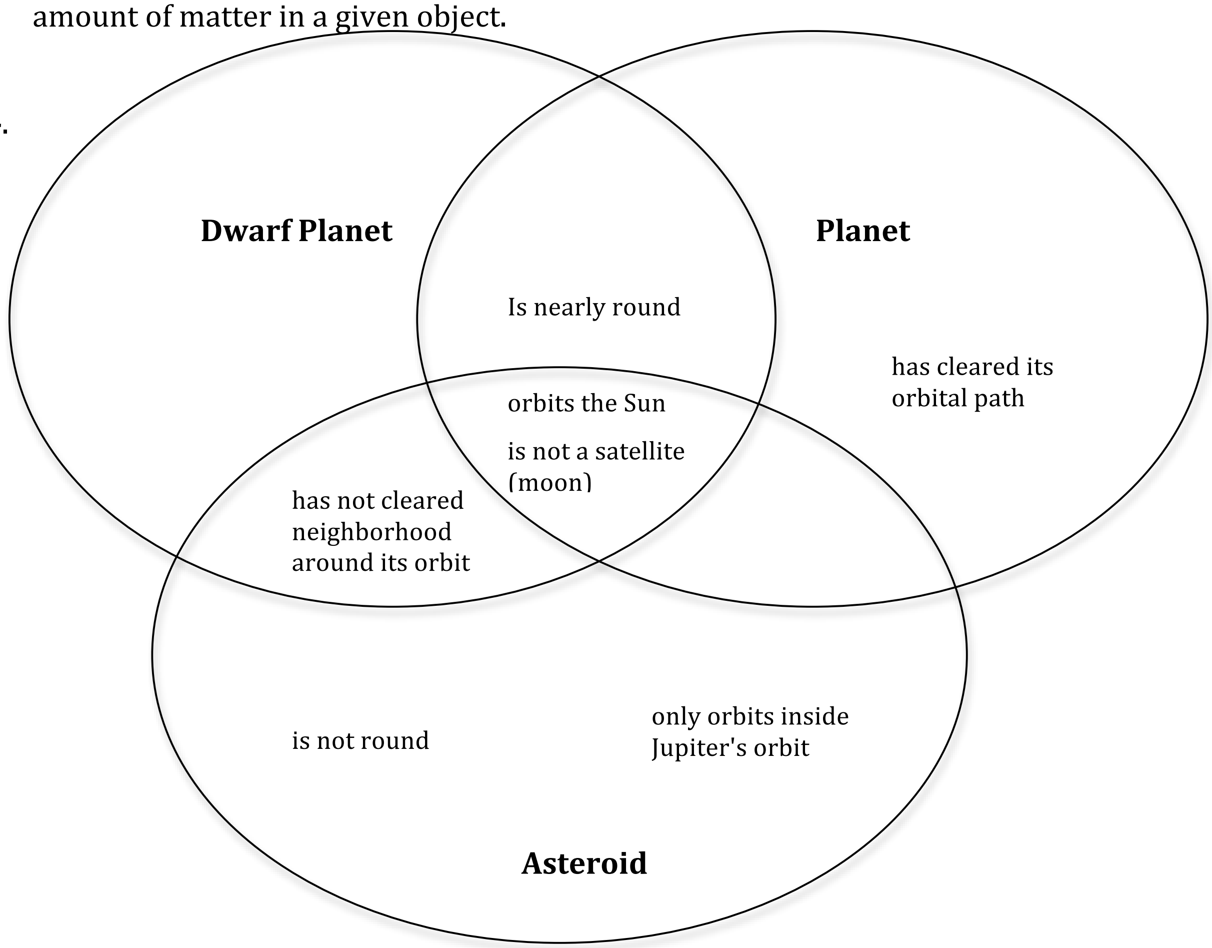
Vesta Concept Quiz Answer Key

1. Planetary bodies build by collecting smaller pieces of unrelated materials such as stardust. The process is called accretion.

2. Answers vary, but may include:
    - Gravity affects planetary bodies.
    - Gravity was a force present at the formation of the Solar System.
    - Gravity is a force of attraction pulling any two things toward each other.
    - Gravity keeps the planets in orbit around the Sun.
    - The amount of gravity depends upon the mass of an object.

3. Gravity is the force of attraction pulling two objects together and mass is the amount of matter in a given object.

4.



5. Meteorites are hard to find because most of them look like Earth rocks to an untrained eye. Sometimes they break into fragments when they enter the Earth's atmosphere. They are often black or dull gray and do not stand out.

Name ______________________

Date ______________________

Vocabulary Quiz 1

1. _______ Astronomer	**A.** One of thousands of small, solid planetary bodies orbiting the Sun
2. _______Sphere	**B.** One who studies the science of celestial bodies
3. _______ Gravity	**C.** A push or pull upon an object
4. _______ Accretion	**D.** The process by which rocks are altered in composition, texture, or structure
5. _______ Planet	**E.** Area of the surface with distinctive physical features
6. _______ Chondrite	**F.** A force of attraction pulling any two things to each other, depending on
7. _______ Mass	the mass of objects
	G. The amount of matter in an object
8. _______ Force	**H.** An object that is round or almost round
	I. Any of the eight large, celestial bodies
9. _______ Matrix	revolving around the Sun
	J. Accumulation under the influence of
10. _______ Asteroid	gravity and some minor forces
	K. The forceful striking of one body against
11. _______ Metamorphism	another such as a moon or planet
	L. Stony meteorite containing chondrules
12. _______ Dwarf Planet	embedded in a fine matrix of pyroxene, olivine, and metallic nickel-iron
13. _______ Terrain	**M.** A spherical celestial body revolving around the Sun but not large enough
14. _______ Impact	to gravitationally clear its orbit of other celestial bodies
15. _______ Meteorite	**N.** The smaller sized grains in a rock that consists of large grain fragments surrounded by smaller grains
	O. Metallic or stony body that has fallen on the Earth, Moon, or other planetary body

Vesta Vocabulary Quiz #1 Answer Key

1. B
2. H
3. F
4. J
5. I
6. L
7. G
8. C
9. N
10. A
11. D
12. M
13. E
14. K
15. O

Name _________________________

Date __________________________

Vocabulary Quiz 2

1.________ Vesta

2. ________ Orbit

3. ________ Ellipse

4. ________ Meteor

5. ________ Meteoroid

6. ________ Asteroid Belt

7. ________ Reflectance

8. ________ Crater

9. ________ Impact

10. _______ Ejecta

11. _______ Ceres

12. _______ Rim

A. The amount of light of a particular color reflected by a surface

B. One of the largest asteroids in the Solar System

C. The forceful striking of one body against another

D. The path of an object in space moving around another

E. A hole or depression

F. A dwarf planet that orbits within the asteroid belt

G. A closed curve of oval shape

H. Area between Mars and Jupiter

I. Material thrown out from and deposited around an impact crater

J. A piece of interplanetary matter smaller than one km

K. The border of a landform

L. A relatively small body of matter traveling through interplanetary space

Vesta Vocabulary Quiz 2 Answer Key

1. B
2. D
3. G
4. L
5. J
6. H
7. A
8. E
9. C
10. I
11. F
12. K

Name ___________________________
Date ____________________________

In-Vesta-Gate Post-Test

Match the following words with their definition:

1. _______ Vesta
2. _______ Accretion
3. _______Astronomer
4. _______ Planet
5. _______Meteorite
6. _______ Mass
7. _______ Ejecta
8. _______ Reflectance
9. _______ Orbit
10. _______ Chondrite

A. A metallic or stony body that has fallen on Earth, Moon, or other planetary body
B. Stony meteorite containing chondrule embedded in a fine matrix of pyroxene, olivine, and metallic nickel-iron
C. One who studies the science of celestial bodies
D. One of the largest asteroids in the Solar System
E. The amount of matter in an object
F. The path of an object in space moving around another body
G. Material thrown out from and deposited around impact craters
H. Accumulation under the influence of gravity and some minor forces
I. Any of the eight large celestial bodies revolving around the Sun
J. The amount of light of a particular color reflected by a surface

Write the words true or false in the blank.

11. _________ Gravity is a force.
12. _________ There is no gravity in space.
13. _________ Most asteroids are located between Mercury and Venus.
14. _________ An ellipse is a closed curve of oval shape.
15. _________ Gravity is related to movement, nearness of the Earth, and magnetic fields

Multiple Choice

16. ________ All asteroids:
    A. Are round in shape
    B. Are satellites
    C. Are larger than a planet
    D. Orbit the Sun
17. _________ A planet is:
    A. Not round
    B. Is a satellite
    C. Has cleared the neighborhood around its orbit of most bodies
    D. Is smaller than an asteroid
18. _________ A dwarf planet:
    A. Does not orbit the Sun
    B. Is larger than Earth
    C. Is not round
    D. Has **not** cleared the neighborhood around its orbit
19. ________ Gravity:
    A. Keeps planets in orbit around the Sun
    B. Guides the growth of plants
    C. Exists between objects on Earth
    D. All of the above
20. _________ Craters are:
    A. Holes or depressions in the surface of a planetary body
    B. Not caused by impacts
    C. Only on the Moon
    D. Never changed once they are formed

Short Answer

1. Compare and contrast an asteroid and meteoroid. How are they alike? How are they different?

____

____

____

____

2. If a bowling ball and a marble are dropped in a vacuum from the same height at the same time, which one would land first? Explain your answer.

____

____

____

____

3. If a golf ball and feather are dropped by your teacher at the same time and at the same height, which would land first? Explain. Suppose they were dropped by an astronaut on the Moon, which would land first? Explain your answer.

____

____

____

____

____

4. What is the difference between a meteoroid and a meteorite?

____

____

____

____

5. Although it is possible for the Earth to be hit by a meteorite, it does not happen very often. Explain why?

____

____

____

____

In-Vesta-Gate Post-Test Answer Key

1. D
2. H
3. C
4. I
5. A
6. E
7. G
8. J
9. F
10. B
11. True
12. False
13. False
14. True
15. False
16. D
17. C
18. D
19. D
20. A
21. Asteroids and meteoroids are both celestial bodies. Asteroids are smaller than planets and are usually located in the belt between Mars and Jupiter. They are rocky with no atmosphere; some have high metallic content. Meteoroids are interplanetary bodies that are smaller than asteroids.
22. The bowling ball and marble would land at the same time because they are accelerating at the same rate.
23. The golf ball would land first because the feather is affected by greater air resistance, which is a form of friction. If they were dropped on the Moon, they would land at the same time because they would accelerate at the same rate and there would be no air resistance influencing the feather.
24. A meteoroid is an interplanetary body that often vaporizes when it enters the atmosphere of another object. A meteorite is a meteoroid that has survived to impact the surface.
25. Meteorites do sometimes impact Earth. However, it is rare because the Solar System is mostly empty space.

Appendix B - Educator Feedback/Unit Evaluation

InVESTAgate Educator Survey

Name ___________________________School _______________I teach _____ grade.

1. Think about any lesson or part of a lesson that you tried with your students. Did your students find the lessons/activities engaging? Using the rubric below, please rate each lesson and/or activity, if specified. Write a number from 1 to 4 in the “Rating” column, and explain your choice in “Comments.” If you only did part of a particular lesson, please identify which part.

Not engaging for my students	Somewhat engaging for my students	Engaging enough to hold my students' interests most of the class time	Very engaging-- my students will be excited about this activity
1	2	3	4

Unit Day/LessonTitle/Activity	**Rating**	**Comments**
Day One/Solar System Formation		
Day Two/The Role of Gravity/ Gravity Misconceptions		
Day Two/The Role of Gravity/ Gravity Pulls You Down		
Day Three/It's Not a Planet?		
Day Four/Asteroids, Comets, & Meteoroids		
Day Five/Observing Asteroids		
Day Six/Asteroid Cratering		
Day Seven/Mapping/ CosmoQuest Asteroid Mappers: Vesta		
Day Eight/Expedition Asteroid Part I: Vesta Landing		
Day Nine/Expedition Asteroid Part II: Mining Vesta		
Day Ten/Expedition Asteroid Part III: We Deliver!		
Day Eleven/The Universe is Out to Get You		
Assessment Activities (any or all)		

2. Is the unit content grade-appropriate for your students?

3. Is the unit the right length?

Too long –------------------------------ right length ---------------------------------------– too short

Comments:

4. How easily would you be able to get the supplies necessary if a kit were not provided?

Would not be able to get any supplies	Would not be able to get the expensive supplies	Would be able to get most of the supplies	Already have most of the supplies at my school

5. What might prevent you from using this unit in your classroom?

6. What level of training do you think the average (non-science specialist) teacher needs to successfully conduct this unit?

No training (Can use right out of the box)	1 – hour workshop training	1- day workshop training	Need a science background

7. If you have any other helpful comments or suggestions, please write them below.

Please email completed survey to
educate@cosmoquest.org

Thank you so much for your help!
The CosmoQuest Education Team