Science Unit: ***Space***

Lesson 12: ***Dwarf Planets, Comets and Asteroids***

Summary: Part One: Students use flour covered with a thin layer of cinnamon as a model for a planet's surface. They drop marbles into the flour to visualize how craters are formed. Students measure crater width, graph the results, and search for patterns in the data.

Part Two: Students learn about the orbits of comets and asteroids using a gravity well model.

School Year: 2014/2015

Developed for: Lord Strathcona Elementary School, Vancouver School District

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Grade level: Presented to grade 6/7; appropriate for grades 1 – 7 with age appropriate modifications

Duration of lesson: 1 hour and 20 minutes

Objectives

1. Explore some variables in crater formation using a flour and marble model.
2. Understand how scientists interpret crater images to learn about the geological processes and history of a planet or moon.
3. Experiment with orbit shapes using a gravity well model to learn about the many bodies orbiting our sun.

Background Information

There are many bodies orbiting the sun besides the planets. Evidence of collisions between these bodies are in the craters found on many planets and moons throughout the solar system. Scientists study craters to deduce the size, direction of approach and speed of the impact bodies, to learn about about the type and number of smaller bodies within the asteroid belts and throughout the solar system. In addition, craters tell astronomers about the underlying rock of the planets and moons that are hit, as well as their prevalence of tectonic plate movements and surface erosion (that gradually removes evidence of craters).
The many bodies orbiting the sun have different orbit shapes: the orbits of the asteroids are similar to those of the planets, whereas the dwarf planets and comets have tilted and elongated orbit shapes.

Vocabulary

impact crater	Circular depression on the surface of a planet or moon, caused by the high-speed impact of a smaller body. They usually have a raised rim.
orbit	The curved path of one mass around another, directed by the gravity between them. The Earth and the other planets orbit the Sun, as do the asteroids, dwarf planets and comets. Orbits are usually elliptical in shape, and sometimes almost look circular.
asteroid	Asteroids are small chunks of rock and metal, that are not large enough to form a spherical shape. They are thought to be bodies that never grew large enough to become planets.
dwarf planet	An object orbiting the sun that is large enough to be spherical, but not a planet.
comet	Snowballs of frozen gases, rock and dust, orbiting the sun, sometimes at great distances.

Materials for Crater Formation Activity (for a group of two or three students)

- tray
- flour, enough to have a depth of 10cm deep in the tray
- cinnamon in a shaker
- marble
- metre stick
- spoon or stick (to mix up flour)

Materials for Gravity well Orbit model (for a group of four or five students)

- large circular hoop: hula hoop, or 10 ft length of piping with connector
- spandex fabric to stretch over hoop
- 8 large binder clips
- plastic bag with weight inside e.g. heavy dictionary
- marble and large paper clip to hang bag and weight
- marble for each student

<u>In the Classroom</u>

Introductory Discussion

1. Aside from the planets, there are many other smaller bodies orbiting our Sun.
2. The asteroids, small chunks of rock and metal, are mostly concentrated in the asteroid belt, between Mars and Jupiter. Occasionally, a collision between them sends an asteroid out of the asteroid belt, and it may collide with a planet or moon.
3. Early in the history of our solar system, asteroid impacts were much more common. Now, many of these stray chunks of rock have been caught by the gravity of big planets. Craters on the surface of planets and moons are a result of these collisions.
4. A crater formation activity explores how craters are formed, and how their appearance can teach us about what planets are made of and their history.

Processes of science that the students will focus on: close observation, accurate drawing of observations, accurate measuring, collecting data, graphing data, interpreting graphs, concluding.

Science Activities

Activity 1: Crater Formation

Purpose of Activity: Investigate how impact speed and direction affects crater size and shape.

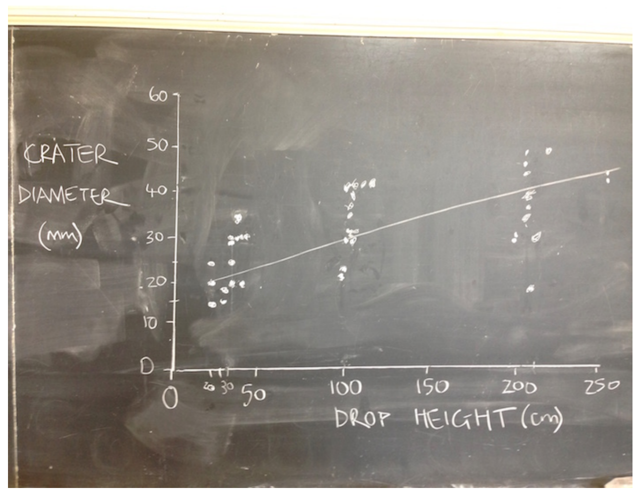
Methods and Instructions:
This activity is adapted from Ref. 1.
Set-up prior to experiment: add the flour to the trays
Students will work in groups of three or four.

1. Demonstrate to students how the activity will work:
2. Students should start by measuring the diameter of their marble (as best they can).
3. Then, shake a tray of flour back and forth so that the surface of the flour is relatively flat. (Do not press the surface down - allow it to settle with its own weight.) Sprinkle cinnamon over the flour to make an even coat of brown over the flour.
4. Hold a metre stick up next to the tray, hold the marble at a designated height on the metre stick, but over the tray, and drop it. The students will see the pattern than the marble makes in the flour (see photo to right).
5. Name the parts of the crater that are formed (see labeled diagram in Ref. 1):
   - *Floor* of the crater (the bottom of the hole)
   - *Rim* (the raised edges ringing the hole)
   - *Ejecta* (material projected out of the crater - it will look white in contrast to the brown cinnamon)
   - *Rays* (long lines extending away from the crater; a pattern made by the ejecta)

5. Show students how to stir up the flour and cinnamon to make an even colour then reapply the cinnamon. They will do this when there are several craters in their tray, and it becomes too hard to take measurements.
6. Tell students that they will be dropping their marble from different heights (the "drop height") and measuring the crater diameter, from rim to rim. They will record their drop height and crater diameters on a worksheet (following this lesson), and should do several trials for each drop height.

Discussion

- Once students have collected data for three different drop heights, ask them to bring their data to a class graph on the board. (If they have time while waiting for others, they can try throwing the marble from an angle into the flour and look at the shape of the crater - see the last question on the worksheet.)



- The class graph should show a positive correlation between drop height and crater diameter, though the results will have wide variation.
- A line can be drawn through the middle of the data to show this correlation. Outliers are ignored. (Stress that this is real data which is why it is messy. This is the case for all real data, and our goal is to find any patterns in it.)
- Point out to students that the marble stays in the hole. When a real crater forms, the impact rock disappears. Ask students where they think it may have gone. (It may have been shattered and been distributed with the ejecta. Or, if the impact generates enough heat, the impactor melts or vapourizes.)
- Ask students what their marble diameter was and compare to the crater sizes they found. (The crater diameters should be larger than the marble because the impact of the marble removes more material from the hole than the space it takes up - this can be seen in the ejecta.)
- Refer students to the graph and point out that for a greater drop height, the crater is larger. A greater drop height means higher speed as it hits. Tell students that scientists can work the other way around: they can figure out the speed of impact by the size of the crater formed. They also look at other features that are made with the very high speeds of meteorites hitting moons and planets - sometimes craters have central uplifts and terraced walls that give more information about the impact.
- Ask students about the patterns of the ejecta:
    - Was the ejecta thrown out evenly in all directions?
    - What appeared to happen to the ray length as the drop height increases?
    - For those students that had time to try it, what happens if the marble comes in from an angle?

  Tell students that scientists look at the shape and pattern of the ejecta to understand more about the impact and the surface material. Show students an image of real ejecta rays e.g. on the Moon (Ref. 2) and Mercury (Ref. 3). The size and angle of the ejector shows them the speed and direction of the impact, in the same way that the rays in the classroom activity reflected the speed and angle of the marble.
- Show students an image of a differently-shaped crater, found on Mars (Ref. 4).
    - Point out that there are no rays.
    - Water or ice present under the impact site melted with the impact, then flowed away instead of being thrown away from the crater. This alternative pattern of ejected material can be used as a way to identify areas with possible water or ice in the surface layers of a planet.

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- Explain that there is additional information that scientists can glean from craters:
  - The number of craters on a surface can tell scientists about a planet's climate and history. Lots of craters indicate that there is no atmosphere to burn up the rocks as they come down (e.g., Mercury). It also may indicate that there are no plate tectonic movements or erosion turning over the planet's surface.
  - Earth and Venus have an atmosphere, which burns up rocks as they pass through (called "meteors" or "shooting stars"). Earth also has moving tectonic plates and erosion that recycle the rocks, removing craters.

Activity 2: Gravity Well and Orbit Shapes

Purpose of Activity: To model the various orbit shapes of planets, meteorites, and comets.

Methods and Instructions:
This activity is adapted from Ref. 5.

Set-up prior to experiment: Stretch the Spandex over the hoop and secure with the binder clips. Support the hoop and fabric with three chairs. Place a marble in the centre of the fabric and push it down, while reaching underneath the fabric to grab the marble (surrounded by fabric). Loop an extended arm of the paper clip around the marble, and use the other arm to hook the bag containing a heavy weight. You should now have a sheet of fabric with a curved well in the centre.

Students will work in groups of 4-6.

1. Introduce students to the various bodies that orbit the sun, other than the planets:
   - *Asteroids* made of rock, metal, or a mixture of both, orbit the sun in an almost circular path. Image at Ref. 6.
   - *Dwarf planets* are smaller than the main planets but large enough for their gravity to pull them into a sphere. They are in the asteroid belt (e.g. dwarf planet Ceres), or in the Kuiper belt (which is beyond Neptune, e.g., Pluto, Eris). The orbits of dwarf planets are more elliptical and tilted than major planets. Image at Reference 7.
   - *Comets* are snowballs of frozen gases, rock and dust the size of a small town. They are found in the Kuiper belt, or beyond. There are billions of them. Images of some comet orbits at Ref. 8. Comets may have brought water and organic compounds (the building blocks of life) to Earth and other bodies in our solar system.
2. Students use the gravity well to model the different orbit shapes around the sun: The fabric represents space, and the funnel in the centre of the fabric represents the gravity of the sun. Using the marbles, students can make the marbles orbit the sun. By varying the shape of the orbit (e.g. circular or elliptical) students can model the orbits of the various bodies orbiting the sun.
3. Put up images of the various orbits (of planets, moons, dwarf planets, asteroids, Kuiper belt objects and comets) so that students can refer to their shapes as they experiment. Planets and asteroids have a circular orbit. Comets have an elliptical orbit.

4. Ask students to notice what happens to the speed of an orbit as the object approaches the gravity well of the sun. (It will speed up.) This happens to the real objects orbiting the sun.
5. Several marbles orbiting at once can represent the asteroid belt, with collisions that knock some of them out of orbit.
6. Discuss the ways that this is not the same as bodies orbiting the sun: (In this model, every marble inevitably loses energy as it rubs against the cloth and falls into the gravity well. Planets stay in orbit around the sun. They are continually falling towards the sun, but their speed means that they curve around it and stay in orbit.)

References

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Extension of Lesson Plan

Try varying other parameters for crater formation, e.g., impactor mass and shape. See Ref. 1 for ideas.