9.E: Cratered Worlds (Exercises)

For Further Exploration

Articles

The Moon

Bakich, Michael. “Asia’s New Assault on the Moon.” *Astronomy* (August 2009): 50. The Japanese Selene and Chinese Chang’e 1 missions.

Beatty, J. “NASA Slams the Moon.” *Sky & Telescope* (February 2010): 28. The impact of the LCROSS mission on the Moon and what we learned from it.

Bell, T. “Warning: Dust Ahead.” *Astronomy* (March 2006): 46. What we know about lunar dust and the problems it can cause.

Dorminey, B. “Secrets beneath the Moon’s Surface.” *Astronomy* (March 2011): 24. A nice timeline of the Moon’s evolution and the story of how we are finding out more about its internal structure.

Jayawardhana, R. “Deconstructing the Moon.” *Astronomy* (September 1998): 40. An update on the giant impact hypothesis for forming the Moon.

Register, B. “The Fate of the Moon Rocks.” *Astronomy* (December 1985): 15. What was done with the rocks the astronauts brought back from the Moon.

Schmitt, H. “Exploring Taurus–Littrow: Apollo 17.” *National Geographic* (September 1973). First-person account given by the only scientist to walk on the Moon.

Schmitt, H. “From the Moon to Mars.” *Scientific American* (July 2009): 36. The only scientist to walk on the Moon reflects on the science from Apollo and future missions to Mars.

Schultz, P. “New Clues to the Moon’s Distant Past.” *Astronomy* (December 2011): 34. Summary of results and ideas from the LCROSS and LRO missions.

Shirao, M. “Kayuga’s High Def Highlights.” *Sky & Telescope* (February 2010): 20. Results from the Japanese mission to the Moon, with high definition TV cameras.

Wadhwa, M. “What Are We Learning from the Moon Rocks?” *Astronomy* (June 2013): 54. Very nice discussion of how the rocks tell us about Moon’s composition, age, and origin.

Wood, Charles. “The Moon’s Far Side: Nearly a New World.” *Sky & Telescope* (January 2007): 48. This article compares what we know about the two sides and why they are different.

Zimmerman, R. “How Much Water is on the Moon?” *Astronomy* (January 2014): 50. Results from the LRO’s instruments and good overview of issue.

Mercury

Beatty, J. “Mercury Gets a Second Look.” *Sky & Telescope* (March 2009): 26. The October 2008 MESSENGER mission flyby.

Beatty, J. “Reunion with Mercury.” *Sky & Telescope* (May 2008): 24. The January 2008 MESSENGER encounter with Mercury.

“Mercury: Meet the Planet Nearest the Sun.” *Sky & Telescope* (March 2014): 39. Four-page pictorial introduction, including the new MESSENGER probe full map of the planet provided.

Oberg, J. “Torrid Mercury’s Icy Poles.” *Astronomy* (December 2013): 30. A nice overview of results from MESSENGER mission, including the ice in polar craters.

Sheehan, W., and Dobbins, T. “Mesmerized by Mercury.” *Sky & Telescope* (June 2000): 109. History of Mercury observations and how amateur astronomers can contribute.

Talcott, R. “Surprises from MESSENGER’s Historic Mercury Fly-by.” *Astronomy* (March 2009): 28.

Talcott, R. “Mercury Reveals its Hidden Side.” *Astronomy* (May 2008): 26. Results and image from the MESSENGER mission flyby of January 2008.

Websites

The Moon

Apollo Lunar Surface Journal: http://www.hq.nasa.gov/office/pao/History/alsj/. Information, interviews, maps, photos, video and audio clips, and much more on each of the Apollo landing missions.

Lunar & Planetary Institute: http://www.lpi.usra.edu/lunar/missions/. Lunar Science and Exploration web pages.

Lunar Reconnaissance Orbiter Mission Page: http://lro.gsfc.nasa.gov/.

NASA's Guide to Moon Missions and Information: nssdc.gsfc.nasa.gov/planetary.../moonpage.html.

Origin of the Moon: www.psi.edu/projects/moon/moon.html. By William Hartmann, who, with a colleague, first suggested the giant impact hypothesis for how the Moon formed, in 1975.

Sky & Telescope magazine's observing guides and articles about the Moon: http://www.skyandtelescope.com/obser...to-watch/moon/.

To the Moon: http://www.pbs.org/wgbh/nova/tothemoon/. PBS program on the Apollo landings.

We Choose the Moon: http://wechoosethemoon.org/. A recreation of the Apollo 11 mission.

Mercury

Mercury Unveiled by G. Jeffrey Taylor (summarizing the Mariner 10 Mission): www.psrd.hawaii.edu/Jan97/MercuryUnveiled.html.

MESSENGER Mission Website: http://messenger.jhuapl.edu/.

NASA Planetary Data Center Mercury Page: nssdc.gsfc.nasa.gov/planetary...rcurypage.html.

Views of the Solar System Mercury Page: http://solarviews.com/eng/mercury.htm.

Collaborative Group Activities

1. We mentioned that no nation on Earth now has the capability to send a human being to the Moon, even though the United States once sent 12 astronauts to land there. What does your group think about this? Should we continue the exploration of space with human beings? Should we put habitats on the Moon? Should we go to Mars? Does humanity have a "destiny in space?" Whatever your answer to these questions, make a list of the arguments and facts that support your position.
2. When they hear about the giant impact hypothesis for the origin of the Moon, many students are intrigued and wonder why we can't cite more evidence for it. In your group, make a list of reasons we cannot find any traces on Earth of the great impact that formed the Moon?
3. We discussed that the ice (mixed into the soil) that is found on the Moon was most likely delivered by comets. Have your group make a list of all the reasons the Moon would not have any ice of its own left over from its early days.
4. Can your group make a list of all the things that would be different if Earth had no Moon? Don't restrict your answer to astronomy and geology. Think about our calendars and moonlit romantic strolls, for example. (You may want to review Earth, Moon, and Sky.)
5. If, one day, humanity decides to establish a colony on the Moon, where should we put it? Make a list of the advantages and disadvantages of locating such a human habitat on the near side, the far side, or at the poles. What site would be best for doing visible-light and radio astronomy from observatories on the Moon?
6. A member of the class (but luckily, not a member of your group) suggests that he has always dreamed of building a vacation home on the planet Mercury. Can your group make a list of all reasons such a house would be hard to build and keep in good repair?
7. As you've read in this chapter, craters on the Moon are (mostly) named after scientists. (See the official list at: planetarynames.wr.usgs.gov/Se...ter,%20craters). The craters on Mercury, on the other hand, are named for writers, artists, composers, and others in the humanities. See the official list at: planetarynames.wr.usgs.gov/SearchResults?target=MERCURY&featureType=Crater,%20craters). Living persons are not eligible. Can each person in your group think of a scientist or someone in the arts whom they especially respect? Now check to see if they are listed. Are there scientists or people in the arts who should have their names on the Moon or Mercury and do not?
8. Imagine that a distant relative, hearing you are taking an astronomy course, calls you up and tells you that NASA faked the Moon landings. His most significant argument is that all the photos of the Moon show black skies, but none of them have any

stars showing. This proves that the photos were taken against a black backdrop in a studio and not on the Moon. Based on your reading in this chapter, what arguments can your group come up with to rebut this idea?

Review Questions

1. What is the composition of the Moon, and how does it compare to the composition of Earth? Of Mercury?
2. Why does the Moon not have an atmosphere?
3. What are the principal features of the Moon observable with the unaided eye?
4. Frozen water exists on the lunar surface primarily in which location? Why?
5. Outline the main events in the Moon's geological history.
6. What are the maria composed of? Is this material found elsewhere in the solar system?
7. The mountains on the Moon were formed by what process?
8. With no wind or water erosion of rocks, what is the mechanism for the creation of the lunar "soil?"
9. What differences did Grove K. Gilbert note between volcanic craters on Earth and lunar craters?
10. Explain how high-speed impacts form circular craters. How can this explanation account for the various characteristic features of impact craters?
11. Explain the evidence for a period of heavy bombardment on the Moon about 4 billion years ago.
12. How did our exploration of the Moon differ from that of Mercury (and the other planets)?
13. Summarize the four main hypotheses for the origin of the Moon.
14. What are the difficulties with the capture hypothesis of the Moon's origin?
15. What is the main consequence of Mercury's orbit being so highly eccentric?
16. Describe the basic internal structure of Mercury.
17. How was the rotation rate of Mercury determined?
18. What is the relationship between Mercury's rotational period and orbital period?
19. The features of Mercury are named in honor of famous people in which fields of endeavor?
20. What do our current ideas about the origins of the Moon and Mercury have in common? How do they differ?

Thought Questions

1. One of the primary scientific objectives of the Apollo program was the return of lunar material. Why was this so important? What can be learned from samples? Are they still of value now?
2. Apollo astronaut David Scott dropped a hammer and a feather together on the Moon, and both reached the ground at the same time. What are the two distinct advantages that this experiment on the Moon had over the same kind of experiment as performed by Galileo on Earth?
3. Galileo thought the lunar maria might be seas of water. If you had no better telescope than the one he had, could you demonstrate that they are not composed of water?
4. Why did it take so long for geologists to recognize that the lunar craters had an impact origin rather than a volcanic one?
5. How might a crater made by the impact of a comet with the Moon differ from a crater made by the impact of an asteroid?
6. Why are the lunar mountains smoothly rounded rather than having sharp, pointed peaks (as they were almost always depicted in science-fiction illustrations and films before the first lunar landings)?
7. The lunar highlands have about ten times more craters in a given area than do the maria. Does this mean that the highlands are 10 times older? Explain your reasoning.
8. At the end of the section on the lunar surface, your authors say that lunar night and day each last about two Earth weeks. After looking over the information in Earth, Moon, and Sky and this chapter about the motions of the Moon, can you explain why? (It helps to draw a diagram for yourself.)
9. Give several reasons Mercury would be a particularly unpleasant place to build an astronomical observatory.
10. If, in the remote future, we establish a base on Mercury, keeping track of time will be a challenge. Discuss how to define a year on Mercury, and the two ways to define a day. Can you come up with ways that humans raised on Earth might deal with time cycles on Mercury?
11. The Moon has too little iron, Mercury too much. How can both of these anomalies be the result of giant impacts? Explain how the same process can yield such apparently contradictory results.

Figuring for Yourself

1. In the future, astronomers discover a solid moon around a planet orbiting one of the nearest stars. This moon has a diameter of 1948 km and a mass of 1.6×10^{22} kg. What is its density?
2. The Moon was once closer to Earth than it is now. When it was at half its present distance, how long was its period of revolution? (See Orbits and Gravity for the formula to use.)
3. Astronomers believe that the deposit of lava in the giant mare basins did not happen in one flow but in many different eruptions spanning some time. Indeed, in any one mare, we find a variety of rock ages, typically spanning about 100 million years. The individual lava flows as seen in Hadley Rille by the Apollo 15 astronauts were about 4 m thick. Estimate the average time interval between the beginnings of successive lava flows if the total depth of the lava in the mare is 2 km.
4. The Moon requires about 1 month (0.08 year) to orbit Earth. Its distance from us is about 400,000 km (0.0027 AU). Use Kepler's third law, as modified by Newton, to calculate the mass of Earth relative to the Sun.
