3.E: Orbits and Gravity (Exercises)

For Further Exploration

Articles

Brahe and Kepler

Christianson, G. “The Celestial Palace of Tycho Brahe.” *Scientific American* (February 1961): 118.

Gingerich, O. “Johannes Kepler and the Rudolphine Tables.” *Sky & Telescope* (December 1971): 328. Brief article on Kepler’s work.

Wilson, C. “How Did Kepler Discover His First Two Laws?” *Scientific American* (March 1972): 92.

Newton

Christianson, G. “Newton’s *Principia*: A Retrospective.” *Sky & Telescope* (July 1987): 18.

Cohen, I. “Newton’s Discovery of Gravity.” *Scientific American* (March 1981): 166.

Gingerich, O. “Newton, Halley, and the Comet.” *Sky & Telescope* (March 1986): 230.

Sullivant, R. “When the Apple Falls.” *Astronomy* (April 1998): 55. Brief overview.

The Discovery of Neptune

Sheehan, W., et al. “The Case of the Pilfered Planet: Did the British Steal Neptune?” *Scientific American*(December 2004): 92.

Websites

Brahe and Kepler

Johannes Kepler: His Life, His Laws, and Time: kepler.nasa.gov/Mission/JohannesKepler/. From NASA’s Kepler mission.

Johannes Kepler: http://www.britannica.com/biography/Johannes-Kepler. Encyclopedia Britannica article.

Johannes Kepler: www-history.mcs.st-andrews.ac...es/Kepler.html. MacTutor article with additional links.

Noble Dane: Images of Tycho Brahe: http://www.mhs.ox.ac.uk/tycho/index.htm. A virtual museum exhibit from Oxford.

Newton

Sir Isaac Newton: www-groups.dcs.st-and.ac.uk/~...es/Newton.html. MacTutor article with additional links.

Sir Isaac Newton: http://www.luminarium.org/sevenlit/n.../newtonbio.htm. Newton Biography at the Luminarium.

The Discovery of Neptune

Adams, Airy, and the Discovery of Neptune: http://www.mikeoates.org/lassell/adams-airy.htm. A defense of Airy’s role by historian Alan Chapman.

Mathematical Discovery of Planets: www-groups.dcs.st-and.ac.uk/~...and_Pluto.html. MacTutor article.

Videos

Brahe and Kepler

“Harmony of the Worlds.” This third episode of Carl Sagan’s TV series *Cosmos* focuses on Kepler and his life and work.

Tycho Brahe, Johannes Kepler, and Planetary Motion: https://www.youtube.com/watch?v=x3ALuycrCwI. German-produced video, in English (14:27).

Newton

Beyond the Big Bang: Sir Isaac Newton’s Law of Gravity: http://www.history.com/topics/enligh...law-of-gravity. From the History Channel (4:35).

Sir Isaac Newton versus Bill Nye: Epic Rap Battles of History: https://www.youtube.com/watch?v=8yis7GzlXNM. (2:47).

The Discovery of Neptune

Richard Feynman: On the Discovery of Neptune: https://www.youtube.com/watch?v=FgXQffVgZRs. A brief black-and-white Caltech lecture (4:33).

Collaborative Group Activities

1. An eccentric, but very rich, alumnus of your college makes a bet with the dean that if you drop a baseball and a bowling ball from the tallest building on campus, the bowling ball would hit the ground first. Have your group discuss whether you would make a side bet that the alumnus is right. How would you decide who is right?
2. Suppose someone in your astronomy class was unhappy about his or her weight. Where could a person go to weigh one-fourth as much as he or she does now? Would changing the unhappy person's weight have any effect on his or her mass?
3. When the Apollo astronauts landed on the Moon, some commentators commented that it ruined the mystery and "poetry" of the Moon forever (and that lovers could never gaze at the full moon in the same way again). Others felt that knowing more about the Moon could only enhance its interest to us as we see it from Earth. How do the various members of your group feel? Why?
4. Figure 3.5.2 shows a swarm of satellites in orbit around Earth. What do you think all these satellites do? How many categories of functions for Earth satellites can your group come up with?
5. The Making Connections feature box Astronomy and the Poets discusses how poets included the most recent astronomical knowledge in their poetry. Is this still happening today? Can your group members come up with any poems or songs that you know that deal with astronomy or outer space? If not, perhaps you could find some online, or by asking friends or roommates who are into poetry or music.

Review Questions

1. State Kepler's three laws in your own words.
2. Why did Kepler need Tycho Brahe's data to formulate his laws?
3. Which has more mass: an armful of feathers or an armful of lead? Which has more volume: a kilogram of feathers or a kilogram of lead? Which has higher density: a kilogram of feathers or a kilogram of lead?
4. Explain how Kepler was able to find a relationship (his third law) between the orbital periods and distances of the planets that did not depend on the masses of the planets or the Sun.
5. Write out Newton's three laws of motion in terms of what happens with the momentum of objects.
6. Which major planet has the largest . . .
    1. semimajor axis?
    2. average orbital speed around the Sun?
    3. orbital period around the Sun?
    4. eccentricity?
7. Why do we say that Neptune was the first planet to be discovered through the use of mathematics?
8. Why was Brahe reluctant to provide Kepler with all his data at one time?
9. According to Kepler's second law, where in a planet's orbit would it be moving fastest? Where would it be moving slowest?
10. The gas pedal, the brakes, and the steering wheel all have the ability to accelerate a car—how?
11. Explain how a rocket can propel itself using Newton's third law.
12. A certain material has a mass of 565 g while occupying 50 cm3 of space. What is this material? (Hint: Use Table 3.2.1.)
13. To calculate the momentum of an object, which properties of an object do you need to know?
14. To calculate the angular momentum of an object, which properties of an object do you need to know?
15. What was the great insight Newton had regarding Earth's gravity that allowed him to develop the universal law of gravitation?
16. Which of these properties of an object best quantifies its inertia: velocity, acceleration, volume, mass, or temperature?
17. Pluto's orbit is more eccentric than any of the major planets. What does that mean?
18. Why is Tycho Brahe often called "the greatest naked-eye astronomer" of all time?

Thought Questions

1. Is it possible to escape the force of gravity by going into orbit around Earth? How does the force of gravity in the International Space Station (orbiting an average of 400 km above Earth's surface) compare with that on the ground?
2. What is the momentum of an object whose velocity is zero? How does Newton's first law of motion include the case of an object at rest?

3. Evil space aliens drop you and your fellow astronomy student 1 km apart out in space, very far from any star or planet. Discuss the effects of gravity on each of you.
4. A body moves in a perfectly circular path at constant speed. Are there forces acting in such a system? How do you know?
5. As friction with our atmosphere causes a satellite to spiral inward, closer to Earth, its orbital speed increases. Why?
6. Use a history book, an encyclopedia, or the internet to find out what else was happening in England during Newton's lifetime and discuss what trends of the time might have contributed to his accomplishments and the rapid acceptance of his work.
7. Two asteroids begin to gravitationally attract one another. If one asteroid has twice the mass of the other, which one experiences the greater force? Which one experiences the greater acceleration?
8. How does the mass of an astronaut change when she travels from Earth to the Moon? How does her weight change?
9. If there is gravity where the International Space Station (ISS) is located above Earth, why doesn't the space station get pulled back down to Earth?
10. Compare the density, weight, mass, and volume of a pound of gold to a pound of iron on the surface of Earth.
11. If identical spacecraft were orbiting Mars and Earth at identical radii (distances), which spacecraft would be moving faster? Why?

Figuring for Yourself

1. By what factor would a person's weight be increased if Earth had 10 times its present mass, but the same volume?
2. Suppose astronomers find an earthlike planet that is twice the size of Earth (that is, its radius is twice that of Earth's). What must be the mass of this planet such that the gravitational force (Fgravity) at the surface would be identical to Earth's?
3. What is the semimajor axis of a circle of diameter 24 cm? What is its eccentricity?
4. If 24 g of material fills a cube 2 cm on a side, what is the density of the material?
5. If 128 g of material is in the shape of a brick 2 cm wide, 4 cm high, and 8 cm long, what is the density of the material?
6. If the major axis of an ellipse is 16 cm, what is the semimajor axis? If the eccentricity is 0.8, would this ellipse be best described as mostly circular or very elongated?
7. What is the average distance from the Sun (in astronomical units) of an asteroid with an orbital period of 8 years?
8. What is the average distance from the Sun (in astronomical units) of a planet with an orbital period of 45.66 years?
9. In 1996, astronomers discovered an icy object beyond Pluto that was given the designation 1996 TL 66. It has a semimajor axis of 84 AU. What is its orbital period according to Kepler's third law?
