3.2 Universal Gravitation

This section describes and analyzes gravitational forces acting on objects at a distance from Earth's surface. This is achieved by discussing the historical background, mathematical relationships, and applications of Newton's law of universal gravitation.

Achievement Chart Categories	Assessment Opportunities/Specific Expectation Addressed	Assessment Tools
Knowledge/Understanding	Practice Questions Understanding Concepts, q. 1–9 FM1.05 Section 3.2 Questions Understanding Concepts, q. 1–3 FM1.05	Rubric 1: Knowledge/Understanding
Inquiry	Section 3.2 Questions Applying Inquiry Skills, q. 4 FM1.05	Rubric 2: Inquiry Skills
Communication	Section 3.2 Questions Making Connections, q. 5 FM1.05	Rubric 3: Communication
Making Connections	Section 3.2 Questions Making Connections, q. 6–8 FM3.03	Rubric 4: Making Connections

Expectations Addressed

Overall Expectations—FMV.03
Overall Skills Expectations—SIS.04, SIS.06, SIS.08, SIS.09
Specific Expectations:

- FM1.05 analyze and describe the gravitational force acting on an object near, and at a distance from, the surface of the Earth
- FM3.01 explain how the contributions of Galileo and Newton revolutionized the scientific thinking of their time and provided the foundation for understanding the relationship between motion and force
- FM3.03 analyze and explain the relationship between an understanding of forces and motion and an understanding of political, economic, environmental, and safety issues in the development and use of transportation technologies (including terrestrial and space vehicles) and recreation and sports equipment

BACKGROUND INFORMATION

It is because of the force of gravity that stars and the planetary systems around stars form. Thus, an interesting context for the study of universal gravitation is the formation of planets elsewhere in the universe.

Newton's understanding of the force of gravity in the solar system was a great step forward in scientific reasoning. His law of universal gravitation is developed first using variation statements and then using the equation in which the universal gravitation constant, G, is explained and applied. A discussion regarding the constancy of this "constant" has profound implications for understanding the future of the universe, but such a discussion is well beyond the scope of this book.

The experiment devised by Henry Cavendish to determine the value of the constant, G, can be compared with the experiment devised to determine the value of the constant k in Coulomb's law of electrostatic charges (see page 433 of the text).

The section includes applications of gravitational forces in the solar system and in other parts of the universe. A more complete explanation of the motion of satellites (both natural and artificial) is part of the grade 12 physics course in which Newton's law of universal gravitation is combined with Kepler's laws of planetary motion.

ADDRESSING ALTERNATIVE CONCEPTIONS

Although the story that an apple that struck Isaac Newton on the head enabled him to conjure up the theory of universal gravitation is interesting, it is irrelevant to the concepts and mathematical treatment in this section. Whether or not the story is true, certainly Newton must be considered extremely brilliant for realizing that the force that pulls an apple toward the ground also pulls on the Moon, keeping it in its orbit around Earth.

An important concept to reinforce is that the mathematical proportionalities related to the law of universal gravitation apply only to the cases described near the bottom of page 91. They do not apply to non-spherical objects in close proximity, such as two humans in the same room. (The latter may make for an interesting practice or test question, but it fosters a misconception.)

Students should realize that at any particular instant, there are (generally) two high tides and two low tides that affect Earth's oceans (see pages 93–4). But students at this level should not be held responsible for explaining the forces on the water that cause these tides, especially the explanation of the high tides on the side of Earth opposite the Moon. (The explanation is touched on lightly in this section, but details are left for more advanced resources.)

Black holes are mentioned in the Did You Know? feature on page 95. Some students may have the impression from movies and television shows that a black hole can suck in matter located huge distances away. This is untrue: the gravitational attraction of a black hole is extremely large only at close proximity, as is evident when the inverse square law is applied to calculations.

Related Background Resources

Nelson Web site:
www. science.nelson.com
for specific Web links

NASA: www.nasa.gov

PLANNING

Suggested Time

Narrative/Practice Questions—35 to 45 minutes
Section Questions—20 to 30 minutes

Core Instructional Resources

- Solutions Manual
- Colour Transparencies
- Reference to the Appendixes: Appendix C

Supplemental Resources

- Lab and Study Blackline Masters

TEACHING SUGGESTIONS

- Relate the inverse square relationship between the force of gravitational attraction and the distance separating two objects to the Try This Activity (page 83). (See also Practice Question 1, page 91.)
- Use magnets to set up a model of Cavendish's experiment that enabled him to determine the gravitational constant, *G*.
- Have a globe in class to illustrate tides on the oceans as well as the motion of geosynchronous satellites. (See also Making Connections question 5, page 95.) Have students estimate where the satellite would be located in the classroom. To do this, the students need to estimate the radius of the globe, and they need to know Earth's radius (see Appendix C, page 577) and the fact that a geosynchronous orbit is 36 000 km above Earth's surface.
- To stimulate interest in the vastness of the universe, share with the students one of the Hubble Deep Field images, available on NASA's Web site, or refer to *Nelson Science 9* (published in 1999), pages 480–81.