Gravitational Fields Review

2.1 Exploration of Space

Be able to:

- describe planetary motion using Kepler's Laws
- solve problems using Kepler's Laws
- describe Newton's Law of Universal Gravitation
- solve problems involving Newton's Law of Universal Gravitation
- calculate gravitational potential energy using Newton's Law of Universal Gravitation
- solve escape velocity and binding energy problems

2.2 Low Earth Orbit

Be able to:

- calculate *g* using Newton's Law of Universal Gravitation
- outline Newton's thought experiment regarding satellite motion
- use Newton's Law of Universal Gravitation and circular motion to describe the motion of a satellite
- solve problems involving satellite motion
- define microgravity and describe conditions under which it can be produced

Problems

1. Comet Halley returns every 76 years. Find the average distance of the comet from the sun. ($2.67 \times 10^{12}\ m$)

2. You wish to launch a satellite that will remain above the same spot on Earth's surface. This means the satellite must have a period of exactly one day. Calculate the radius of the circular orbit this satellite must have. **Hint**: The moon also circles Earth and both the moon and the satellite will obey Kepler's third law. The moon is $3.8 \times 10^8\ m$ from Earth and its period is 27.33 days. ($4.19 \times 10^7\ m$)

3. The mass of an electron is $9.1 \times 10^{-31}\ kg$. The mass of a proton is $1.7 \times 10^{-27}\ kg$. They are about $1.0 \times 10^{-10}\ m$ apart in a hydrogen atom. What gravitational force exists between the proton and electron of a hydrogen atom? ($1.03 \times 10^{-47}\ N$)

4. Two $1.00\ kg$ masses have their centers $1.00\ m$ apart. What is the force of attraction between them? ($6.67 \times 10^{-11}\ N$)

5. If the centers of Earth and the moon are $3.9 \times 10^8\ m$ apart, the gravitational force between them is about $1.9 \times 10^{20}\ N$. What is the approximate mass of the moon? ($7.25 \times 10^{22}\ kg$)

6. What would be the value of g, acceleration of gravity, if Earth's mass was double its actual value, but its radius remained the same? If the radius was doubled, but the mass remained the same? If both the mass and radius were doubled? ($19.6\ m/s^2$, $2.45\ m/s^2$, $4.9\ m/s^2$)

7. A satellite is placed in a circular orbit with a radius of $1.0 \times 10^7\ m$ and a period of $9.9 \times 10^3\ s$. Calculate the mass of Earth. **Hint**: Gravity supplies the needed centripetal force for such a satellite. Scientists have actually measured the mass of Earth this way. ($6.0 \times 10^{24}\ kg$)

8. Calculate the period of Earth's moon if the radius of orbit was twice the actual value of $3.9 \times 10^8\ m$. (77.3 days)

9. Use your Table of Useful Planetary Data to find the speed and period of a satellite that would orbit Mars 175 *km* above its surface. (3433 *m/s*, 6598 *s* or 1.83 *h*)

10. A space vehicle, launched as a lunar probe, arrives at the upper limit of Earth's atmosphere. At this point, its kinetic energy is $5.0 \times 10^9\ J$ and its gravitational potential energy is $-6.4 \times 10^9\ J$. What is its binding energy? ($1.4 \times 10^9\ J$)

11. Calculate the escape velocity from our solar system (i.e. from the surface of the sun). (616479 *m/s*)

12. The space shuttle ejects a 1200 kg booster tank so that the tank is momentarily at rest at an altitude of 2000 km. Neglecting atmospheric effects, determine:

a) how much work must be done on the booster by the force of gravity in returning it to Earth's surface. ($-1.79\times10^{10}\ J$)

b) the velocity with which it strikes Earth's surface. (5463 *m/s*)

13. A 500 kg satellite is in circular orbit 200 km above Earth's surface. Calculate

a) the gravitational potential energy of the satellite. ($-3.03\times10^{10}\ J$)

b) the kinetic energy of the satellite. ($1.52\times10^{10}\ J$)

c) its binding energy. ($+1.52\times10^{10}\ J$)

14. A rocket, of mass $1.00\times10^{4}\ kg$ is located $1.00\times10^{10}\ m$ from Earth's center.

a) Determine its gravitational potential energy at this point, considering only Earth. ($-3.99\times10^{8}\ J$)

b) How much kinetic energy must it have, at this point, to be capable of escaping from Earth's gravitational field? ($> 3.99\times10^{8}\ J$)

c) What is the escape velocity from Earth, at this point? (282 *m/s*)

15. The mass of the moon is approximately $6.7\times10^{22}\ kg$, and its radius is $1.6\times10^{6}\ m$. With what velocity must an object be projected from the moon's surface in order to rise to an altitude equal to the moon's radius? (1671 *m/s*)