EXERCISES

Conceptual Questions

1. Why do we not require the more general form of Newton's law of universal gravitation when we are calculating the force of gravity in our classroom?
2. Explain the difference in launch requirements if a spacecraft was launched westward instead of eastward. Assume that it will achieve the same orbit.
3. Why does only one side of the Moon face Earth at all times?
4. Explain the relationship between the force of gravity and gravitational potential energy.
5. If a spacecraft jettisoned a large piece of itself into space, making its new mass about 26% of its original mass, what happens to the orbit of the smaller section?
6. During a space rendezvous, two spacecraft have to match orbits very carefully before one of them can move in to dock. If an astronaut in the shuttle simply points at the other docking craft in the distance and then rockets toward it, the docking spacecraft will move farther away! Why?
7. In a Jules Verne novel, a spacecraft is "shot" to the Moon in a large cannon. Suppose the barrel is 80 m long. If the spacecraft experienced constant acceleration for the entire 80 m, determine
   a) if this mission would be survivable. Explain the reasons carefully.
   b) the force of the cannon's recoil.
8. Assume that our knees can absorb the impact from a fall of 2 m without damage. If we attach springs to our feet that have 500-N/m spring constants and 0.45 m of travel, from what maximum height could we survive a fall?
9. Using the same "spring boots" as in question 8, if the spring completely compresses and our knees absorb their maximum amount of energy, would we bounce off the ground? Explain.
10. Identify three SHMs in your daily experience. Explain how you are convinced that the motion is in fact typical of SHM.
11. Find three examples of damping in oscillatory systems (it need not be exactly SHM). Is the damping desired or undesired? Why?
12. Design a device that could be used for measuring the mass of Canadian astronaut Roberta Lynn Bondar while in orbit. Due to continual free fall, she appears weightless, thus rendering conventional scales useless.

Problems

6.1 Gravity and Energy

13. If a 100 000-kg shuttle enters Earth's atmosphere at 4 km/s and lands at 80 m/s, how much energy has it released to the atmosphere? What is its change in height if its initial height was 100 km?
14. A 920-kg satellite is projected vertically upward from Earth's surface with an initial kinetic energy of 7.0×10^9 J. Find
    a) its maximum height.
    b) the initial kinetic energy it would have needed to keep going indefinitely.
    c) the initial speed it would have needed to keep going indefinitely.
15. A 550-kg satellite projected upward from Earth's surface reaches a maximum height of 6000 km. Find
    a) its change in gravitational potential energy.
    b) its initial kinetic energy.

16. A 20 000-kg meteorite from outer space is headed directly toward Earth with a speed of 3.0 km/s. Find its speed when it is 200 km above Earth's surface.

17. The escape speed at the **event horizon** of a black hole is defined as the speed of light, c. What would the size of Earth have to be for it to be compressed to a back hole?

18. At what location from Earth are the gravitational fields of Earth and the Moon balanced?

19. Find the energy per kilogram required to move a payload from Earth's surface to the Moon's surface.

6.2 Orbits

20. Find the speed of an Earth satellite in orbit 400 km above Earth's surface. What is the period of the orbit?

21. Find the altitude of a communications satellite that is in geostationary Earth orbit above the equator.

22. When the space shuttle delivers a crew to the International Space Station, it usually boosts the orbit of the station from about 320 km to 350 km. How much energy does the shuttle add to the station's orbit?

23. a) Show that speed decreases as the radius of a satellite's orbit increases.
    b) What effect does increasing an orbit's radius have on the period of the satellite?

24. Calculate the Moon's energy in its orbit around Earth.

25. Saturn has a mass of 5.7×10^{26} kg and a radius of 6.0×10^{7} m. What is the minimum speed of a satellite orbiting Saturn?

26. The *Apollo* astronauts were typically in an orbit 100 km above the lunar surface. What is the escape speed from the Moon at this altitude?

27. Given the orbit height in problem 26, how long would it take for the *Apollo* spacecraft to complete one orbit around the Moon?

28. a) Calculate the speed of Mars as it moves about the Sun. Its mean distance from the Sun is 2.28×10^{11} m, its radius is 3.43×10^{6} m, and its mass is 6.37×10^{23} kg.
    b) Calculate the speed required to orbit Mars at an altitude of 80 km.

29. Calculate the escape speed of a spacecraft leaving the Moon's surface.

6.3 Simple Harmonic Motion — An Energy Introduction

30. Three waves pass the end of a pier in every 12 s. If there is 2.4 m between the wave crests, what is the frequency?

31. If a spring with $k = 12$ N/m is connected to a mass of 230 g and set in motion with an amplitude of 26 cm, calculate the speed of the mass as it passes the equilibrium point.

32. A 2.0-kg mass on a spring is extended 0.30 m from the equilibrium position and released. The spring constant is 65 N/m.
    a) What is the initial potential energy of the spring?
    b) What maximum speed does the mass reach?
    c) Find the speed of the mass when the displacement is 0.20 m.

33. For the mass in problem 32, find
    a) its maximum acceleration.
    b) its acceleration when the displacement is 0.20 m.

34. a) The Minas Basin in the Bay of Fundy has the largest tides in the world (around 15 m — see Figure 7.43a). Suppose that a device is stretched across the mouth of the bay for 10 km. As the floats inside it rise and fall with the tide, their motion is converted to electricity. Suppose that the mechanical