CHAPTER 11 Summary

BIG IDEA Some events are periodic in nature. The principles of periodic motion can help us understand everything from the motion of a pendulum to the motion of a wave.

SECTION 1 Simple Harmonic Motion

- In simple harmonic motion, restoring force is proportional to displacement.
- A mass-spring system vibrates with simple harmonic motion, and the spring force is given by Hooke's law.
- For small angles of displacement (<15°), a simple pendulum swings with simple harmonic motion.
- In simple harmonic motion, restoring force and acceleration are maximum at maximum displacement, and speed is maximum at equilibrium.

KEY TERM

simple harmonic motion

SECTION 2 Measuring Simple Harmonic Motion

- The period of a mass-spring system depends only on the mass and the spring constant. The period of a simple pendulum depends only on the string length and the free-fall acceleration.
- Frequency is the inverse of period.

KEY TERMS

amplitude
period
frequency

SECTION 3 Properties of Waves

- As a wave travels, the particles of the medium vibrate around an equilibrium position.
- In a transverse wave, vibrations are *perpendicular* to the direction of wave motion. In a longitudinal wave, vibrations are *parallel* to the direction of wave motion.
- Wave speed equals frequency times wavelength.

KEY TERMS

medium
mechanical wave
transverse wave
crest
trough
wavelength
longitudinal wave

SECTION 4 Wave Interactions

- If two or more waves are moving through a medium, the resultant wave is found by adding the individual displacements together point by point.
- Standing waves are formed when two waves that have the same frequency, amplitude, and wavelength travel in opposite directions and interfere.

KEY TERMS

constructive interference
destructive interference
standing wave
node
antinode

VARIABLE SYMBOLS

Quantities		Units	
$F_{elastic}$	spring force	N	newtons
k	spring constant	N/m	newtons/meter
T	period	s	seconds
f	frequency	Hz	hertz = s^{-1}
λ	wavelength	m	meters

Problem Solving

See **Appendix D: Equations** for a summary of the equations introduced in this chapter. If you need more problem-solving practice, see **Appendix I: Additional Problems.**

CHAPTER 11 Review

Simple Harmonic Motion

REVIEWING MAIN IDEAS

1. What characterizes an object's motion as simple harmonic?

2. List four examples of simple harmonic motion.

3. Does the acceleration of a simple harmonic oscillator remain constant during its motion? Is the acceleration ever zero? Explain.

4. A pendulum is released 40° from its resting position. Is its motion simple harmonic?

5. April is about to release the bob of a pendulum. Before she lets go, what sort of potential energy does the bob have? How does the energy of the bob change as it swings through one full cycle of motion?

CONCEPTUAL QUESTIONS

6. An ideal mass-spring system vibrating with simple harmonic motion would oscillate indefinitely. Explain why.

7. In a simple pendulum, the weight of the bob can be divided into two components: one tangent to the direction of motion of the bob and the other perpendicular to the direction of motion of the bob. Which of these is the restoring force, and why?

PRACTICE PROBLEMS

For problems 8–9, see Sample Problem A.

8. Janet wants to find the spring constant of a given spring, so she hangs the spring vertically and attaches a 0.40 kg mass to the spring's other end. If the spring stretches 3.0 cm from its equilibrium position, what is the spring constant?

9. In preparing to shoot an arrow, an archer pulls a bowstring back 0.40 m by exerting a force that increases uniformly from 0 to 230 N. What is the equivalent spring constant of the bow?

Period and Frequency

REVIEWING MAIN IDEAS

10. A child swings on a playground swing. How many times does the child swing through the swing's equilibrium position during the course of a single period of motion?

11. What is the total distance traveled by an object moving back and forth in simple harmonic motion in a time interval equal to its period when its amplitude is equal to A?

12. How is the period of a simple harmonic vibration related to its frequency?

CONCEPTUAL QUESTIONS

13. What happens to the period of a simple pendulum when the pendulum's length is doubled? What happens when the suspended mass is doubled?

14. A pendulum bob is made with a ball filled with water. What would happen to the frequency of vibration of this pendulum if a hole in the ball allowed water to slowly leak out? (Treat the pendulum as a simple pendulum.)

15. If a pendulum clock keeps perfect time at the base of a mountain, will it also keep perfect time when moved to the top of the mountain? Explain.

16. If a grandfather clock is running slow, how can you adjust the length of the pendulum to correct the time?

17. A simple pendulum can be used as an altimeter on a plane. How will the period of the pendulum vary as the plane rises from the ground to its final cruising altitude?

18. Will the period of a vibrating mass-spring system on Earth be different from the period of an identical mass-spring system on the moon? Why or why not?

PRACTICE PROBLEMS

For problems 19–20, see Sample Problem B.

19. Find the length of a pendulum that oscillates with a frequency of 0.16 Hz.

20. A pendulum that moves through its equilibrium position once every 1.000 s is sometimes called a *seconds pendulum.*
  a. What is the period of any seconds pendulum?
  b. In Cambridge, England, a seconds pendulum is 0.9942 m long. What is the free-fall acceleration in Cambridge?
  c. In Tokyo, Japan, a seconds pendulum is 0.9927 m long. What is the free-fall acceleration in Tokyo?

For problem 21, see Sample Problem C.

21. A spring with a spring constant of 1.8×10^2 N/m is attached to a 1.5 kg mass and then set in motion.
  a. What is the period of the mass-spring system?
  b. What is the frequency of the vibration?

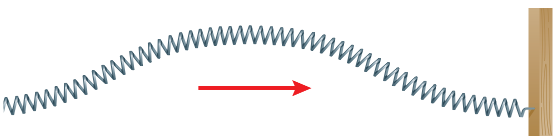
Properties of Waves

REVIEWING MAIN IDEAS

22. What is common to all waves?

23. How do transverse and longitudinal waves differ?

24. The figure below depicts a pulse wave traveling on a spring.
  a. In which direction are the particles of the medium vibrating?



  b. Is this wave transverse or longitudinal?

25. In a stretched spring, several coils are pinched together, and others are spread farther apart than usual. What sort of wave is this?

26. How far does a wave travel in one period?

27. If you shook the end of a rope up and down three times each second, what would be the period of the waves set up in the rope? What would be the frequency?

28. Give three examples of mechanical waves. How are these different from electromagnetic waves, such as light waves?

CONCEPTUAL QUESTIONS

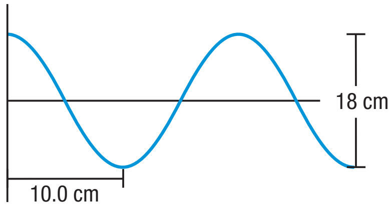
29. How does a single point on a string move as a transverse wave passes by that point?

30. What happens to the wavelength of a wave on a string when the frequency is doubled? What happens to the speed of the wave?

31. Why do sound waves need a medium through which to travel?

32. Two tuning forks with frequencies of 256 Hz and 512 Hz are struck. Which of the sounds will move faster through the air?

33. What is one advantage of transferring energy by electromagnetic waves?



34. A wave traveling in the positive x direction with a frequency of 25.0 Hz is shown in the figure above. Find the following values for this wave:
  a. amplitude
  b. wavelength
  c. period
  d. speed

PRACTICE PROBLEMS

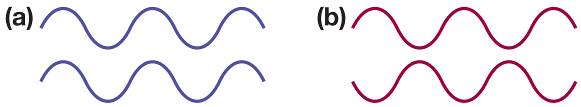
For problem 35, see Sample Problem D.

35. Microwaves travel at the speed of light, 3.00×10^8 m/s. When the frequency of microwaves is 9.00×10^9 Hz, what is their wavelength?

Wave Interactions

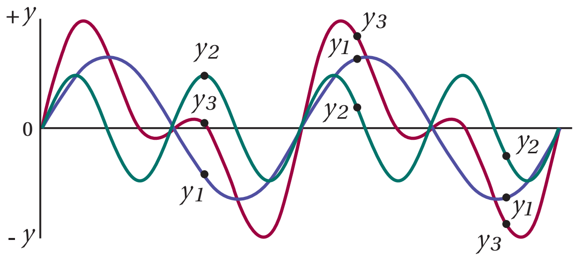
REVIEWING MAIN IDEAS

36. Using the superposition principle, draw the resultant waves for each of the examples below.



37. What is the difference between constructive interference and destructive interference?

38. Which one of the waveforms shown below is the resultant waveform?



39. Anthony sends a series of pulses of amplitude 24 cm down a string that is attached to a post at one end. Assuming the pulses are reflected with no loss of amplitude, what is the amplitude at a point on the string where two pulses are crossing if:

a. the string is rigidly attached to the post?

b. the end at which reflection occurs is free to slide up and down?

CONCEPTUAL QUESTIONS

40. Can more than two waves interfere in a given medium?

41. What is the resultant displacement at a position where destructive interference is complete?

42. When two waves interfere, can the resultant wave be larger than either of the two original waves? If so, under what conditions?

43. Which of the following wavelengths will produce standing waves on a string that is 3.5 m long?

a. 1.75 m

b. 3.5 m

c. 5.0 m

d. 7.0 m

Mixed Review

REVIEWING MAIN IDEAS

44. In an arcade game, a 0.12 kg disk is shot across a frictionless horizontal surface by being compressed against a spring and then released. If the spring has a spring constant of 230 N/m and is compressed from its equilibrium position by 6.0 cm, what is the magnitude of the spring force on the disk at the moment it is released?

45. A child's toy consists of a piece of plastic attached to a spring, as shown at right. The spring is compressed against the floor a distance of 2.0 cm and released. If the spring constant is 85 N/m, what is the magnitude of the spring force acting on the toy at the moment it is released?

46. You dip your finger into a pan of water twice each second, producing waves with crests that are separated by 0.15 m. Determine the frequency, period, and speed of these water waves.

47. A sound wave traveling at 343 m/s is emitted by the foghorn of a tugboat. An echo is heard 2.60 s later. How far away is the reflecting object?

48. The notes produced by a violin range in frequency from approximately 196 Hz to 2637 Hz. Find the possible range of wavelengths in air produced by this instrument when the speed of sound in air is 340 m/s.

49. What is the free-fall acceleration in a location where the period of a 0.850 m long pendulum is 1.86 s?

50. Yellow light travels through a certain glass block at a speed of 1.97×10^8 m/s. The wavelength of the light in this particular type of glass is 3.81×10^{-7} m (381 nm). What is the frequency of the yellow light?

51. A certain pendulum clock that works perfectly on Earth is taken to the moon, where $a_g = 1.63$ m/s^2. If the clock is started at 12:00 A.M., what will it read after 24.0 h have passed on Earth?

ALTERNATIVE ASSESSMENT

1. Design an experiment to compare the spring constant and period of oscillation of a system built with two (or more) springs connected in two ways: in series (attached end to end) and in parallel (one end of each spring anchored to a common point). If your teacher approves your plan, obtain the necessary equipment and perform the experiment.

2. The rule that the period of a pendulum is determined by its length is a good approximation for amplitudes below 15°. Design an experiment to investigate how amplitudes of oscillation greater than 15° affect the motion of a pendulum. List what equipment you would need, what measurements you would perform, what data you would record, and what you would calculate. If your teacher approves your plan, obtain the necessary equipment and perform the experiment.

3. Research earthquakes and different kinds of seismic waves. Create a presentation about earthquakes that includes answers to the following questions as well as additional information: Do earthquakes travel through oceans? What is transferred from place to place as seismic waves propagate? What determines their speed?

4. Identify examples of periodic motion in nature. Create a chart describing the objects involved, their paths of motion, their periods, and the forces involved. Which of the periodic motions are harmonic, and which are not?

5. Research the active noise reduction (ANR) technology used in noise-cancelling headphones. How does it work? What are some other applications that use ANR technology? Choose one application, and create a brochure to explain how it works.

GRAPHING CALCULATOR PRACTICE

Pendulum

Would a pendulum have the same period of oscillation on Mars, Venus, or Neptune? A pendulum's period, as you learned earlier in this chapter, is described by the following equation:

$$T = 2\pi\sqrt{\frac{L}{a_g}}$$

In this equation, T is the period, L is the length of the pendulum, and a_g is the free-fall acceleration (9.81 m/s^2 on Earth's surface). This equation can be rearranged to solve for L if T is known.

$$L = \frac{a_g T^2}{4\pi^2}$$

In this graphing calculator activity, you will enter the period of a pendulum on Earth's surface. The calculator will use the previous equation to determine L, the length of the pendulum. The calculator will then use this length to display a graph showing how the period of this pendulum changes as free-fall acceleration changes. You will use this graph to find the period of a pendulum on various planets.

Go online to HMHScience.com to find the skillsheet and program for this graphing calculator activity.