Vibrations and Waves (introduction): From: textbook "Physics 11", Nelson

Instructions:
The scans posted in this document are from the textbook, "Physics 11" (publisher, Nelson).
The questions and information provide an introduction to the "Waves" unit of Physics 11.

Do the following:
"Are You Ready? Knowledge and Understanding"
Do questions # 2, 3, 4, 5 (recall: speed = distance/time)

Are You Ready?

Knowledge and Understanding

1. If you are positioned outdoors about 20 m from a friend, think of all the ways in which you can attract your friend's attention. Make two lists to classify the ways according to whether or not they involve the sense of hearing or any of your friend's other senses.
2. **Figure 1** shows waves being produced on a rope that has one end tied tightly to a post.
   (a) Where does the energy that produces the waves come from?
   (b) Which wave was produced first, the one in segment A or the one in segment B?
   (c) Did the waves in the two segments take the same amount of time to be produced? How do you know?
   (d) In your notebook, draw a sketch to show how the hand moved to create the waves shown. How many cycles were used?
   (e) What name would you give to the top part of each wave? the bottom part of each wave?
   (f) Use a ruler to estimate in centimetres the "wavelength" of the waves.

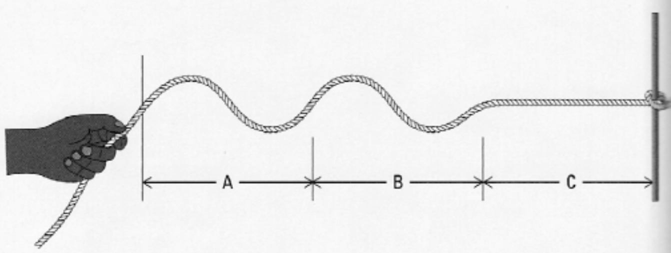


Figure 1
The waves on the rope are moving to the right.

3. Can sound travel in a solid? a liquid? a gas? a vacuum? Give an example of each "yes" answer, and explain any "no" answers that you give.
4. Why are you able to see lightning before you hear the sound of the thunder caused by the lightning strike?
5. You are standing 85 m from a batter who is hitting a baseball. You see the bat touch the ball, but you do not hear the sound made by the hit until 0.24 s after. What is the speed of the sound in air?

READ the following pages and try all the practice questions. The answers to the practice questions are given, so you can check your work. This topic will be included on Test #1 on Sept 27.

6.1 Vibrations

wave: a transfer of energy over a distance, in the form of a disturbance

periodic motion: motion that occurs when the vibration, or oscillation, of an object is repeated in equal time intervals

transverse vibration: occurs when an object vibrates perpendicular to its axis

longitudinal vibration: occurs when an object vibrates parallel to its axis

torsional vibration: occurs when an object twists around its axis

Waves are disturbances that transfer energy over a distance. Water waves, sound waves, waves in a rope, and earthquake waves all originate from objects that are vibrating. For example, a water wave can result from the vibration caused by a boat rocking on the water, while sound waves could originate from a vibrating tuning fork or a vibrating guitar or piano string. In each case, the vibrating source supplies the energy that is transferred through the medium as a wave. Often the objects are vibrating so rapidly that they are difficult to observe with our eyes. For the purpose of studying the properties of vibrating objects, a slowly moving device, such as a mass bouncing up and down on a spring or a swinging pendulum, is ideal.

When an object repeats a pattern of motion—as a bouncing spring does—we say the object exhibits **periodic motion**. The vibration, or oscillation, of the object is repeated over and over with the same time interval each time.

There are three basic types of vibration. A **transverse vibration** occurs when an object vibrates perpendicular to its axis at the normal rest position. An example of a transverse vibration is a child swinging on a swing. A **longitudinal vibration** occurs when an object vibrates parallel to its axis at the rest position. An example is a coil spring supporting a vehicle. A **torsional vibration** occurs when an object twists around its axis at the rest position. An example occurs when a string supporting an object is twisted, causing the object to turn or vibrate around and back. The three kinds of vibration are shown in Figure 1. Throughout this chapter, the term oscillation could also be used instead of vibration.

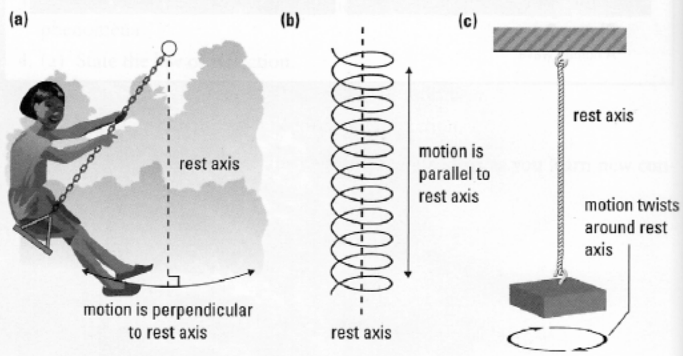


Figure 1
The three basic types of vibration
(a) Transverse vibration
(b) Longitudinal vibration
(c) Torsional vibration

cycle: one complete vibration or oscillation

frequency: (f) the number of cycles per second;

$$f = \frac{\text{number of cycles}}{\text{total time}}$$

hertz: 1 Hz = 1 cycle/s or 1 Hz = 1 s^{-1}, since cycle is a counted quantity, not a measured unit

period: (T) the time required for one cycle;

$$T = \frac{\text{total time}}{\text{number of cycles}}$$

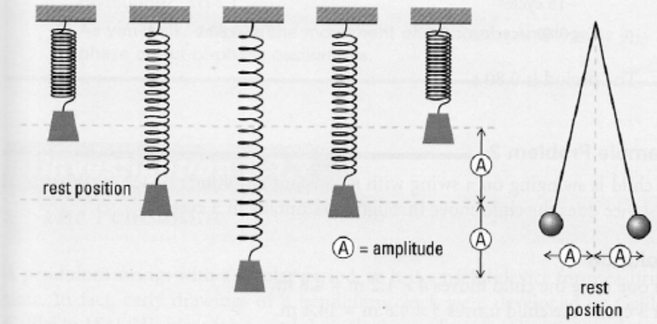
When we describe the motion of a vibrating object, we call one complete oscillation a **cycle** (Figure 2). The number of cycles per second is called the **frequency** (f). The SI unit used to measure frequency is the **hertz** (Hz), named after Heinrich Hertz (1857–1894), the German scientist who first produced electromagnetic waves in the laboratory.

Another term used in describing vibrations is the **period** (T). The period is the time required for one cycle. Usually the second (s) is used for measuring the period, but for a longer period, like that of the rotation of the Moon, the day (d) or the year (yr) is used.

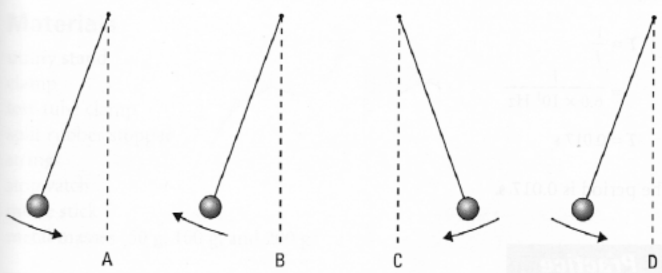
Since frequency is measured in cycles per second and period is measured in seconds per cycle, frequency and period are reciprocals of each other. Thus,

$$f = \frac{1}{T} \quad \text{and} \quad T = \frac{1}{f}$$

As a pendulum swings, it repeats the same motion in equal time intervals. The distance in either direction from the equilibrium, or rest, position to maximum displacement is called the **amplitude** (A) (**Figure 3**).



Two identical pendulums are said to be vibrating **in phase** if they have the same period and pass through the rest position at the same time (**Figure 4**). Two identical pendulums are vibrating **out of phase** if they do not have the same period or if they have the same period but they do not pass through the rest position at the same time.



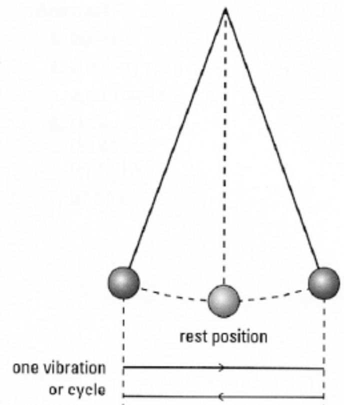


Figure 2
One cycle is equal to one complete vibration.

Figure 3
The rest position is where the object will remain at rest. An object can move through its rest position.

amplitude: distance from the equilibrium position to maximum displacement

in phase: objects are vibrating in phase if they have the same period and pass through the rest position at the same time

out of phase: objects are vibrating out of phase if they do not have the same period or if they have the same period but they do not pass through the rest position at the same time

Figure 4
Pendulums A and D are in phase. Pendulums B and C are not. Why?

Sample Problem 1

A mass hung from a spring vibrates 15 times in 12 s. Calculate (a) the frequency and (b) the period of the vibration.

Solution

(a) number of cycles = 15 cycles
total time = 12 s
$f = ?$
$T = ?$

$$f = \frac{\text{number of cycles}}{\text{total time}}$$

$$= \frac{15 \text{ cycles}}{12 \text{ s}}$$

$$f = 1.2 \text{ cycles/s}$$

The frequency is 1.2 Hz.

(b) $$T = \frac{\text{total time}}{\text{number of cycles}} = \frac{12 \text{ s}}{15 \text{ cycles}}, \quad T = 0.80 \text{ s/cycle, or } 0.80 \text{ s}$$

or

$$T = \frac{1}{f} = \frac{1}{1.2 \text{ Hz}}, \quad T = 0.80 \text{ s}$$

The period is 0.80 s.

Sample Problem 2

A child is swinging on a swing with a constant amplitude of 1.2 m. What total distance does the child move through horizontally in 3 cycles?

Solution

In one cycle the child moves $4 \times 1.2 \text{ m} = 4.8 \text{ m}$.
In 3 cycles the child moves $3 \times 4.8 \text{ m} = 14.4 \text{ m}$.
The child moves 14.4 m in 3 cycles.

Sample Problem 3

The frequency of a wave is 6.0×10^1 Hz. Calculate the period.

Solution

$f = 6.0 \times 10^1 \text{ Hz}$
$T = ?$

$$T = \frac{1}{f}$$

$$= \frac{1}{6.0 \times 10^1 \text{ Hz}}$$

$$T = 0.017 \text{ s}$$

The period is 0.017 s.

Practice

Understanding Concepts

1. State the type of vibration in each of the following:
   (a) a tree sways in the wind
   (b) a sewing-machine needle moves up and down
2. Calculate the period in seconds of each of these motions:
   (a) a pulse beats 25 times in 15 s
   (b) a woman shovels snow at a rate of 15 shovelsful per minute
   (c) a car motor turns at 2450 rpm (revolutions per minute)

Answers

2. (a) 0.60 s
   (b) 4.0 s
   (c) 2.4×10^{-2} s

3. A stroboscope is flashing so that the time interval between flashes is $\frac{1}{80}$ s. Calculate the frequency of the strobe light's flashes.
4. A child on a swing completes 20 cycles in 25 s. Calculate the frequency and the period of the swing.
5. Calculate the frequency and period of a tuning fork that vibrates 2.40×10^4 times in 1.00 min.
6. Calculate the frequency of the following:
   (a) a violin string vibrates 88 times in 0.20 s
   (b) a physics ticker-tape timer produces 3600 dots in 1.0 min
   (c) a CD rotates in a CD player 4.5×10^3 times in 1.0 minute
7. If the Moon orbits Earth six times in 163.8 d, what is its period of revolution?
8. As you walk, describe the movement of your arms and legs as in-phase or out-of-phase oscillations.

Answers

3. 80 Hz
4. 0.80 Hz; 1.2 s
5. 4.00×10^2 Hz; 2.5×10^{-3} s
6. (a) 4.4×10^2 Hz
   (b) 60 Hz
   (c) 75 Hz
7. 27.30 d