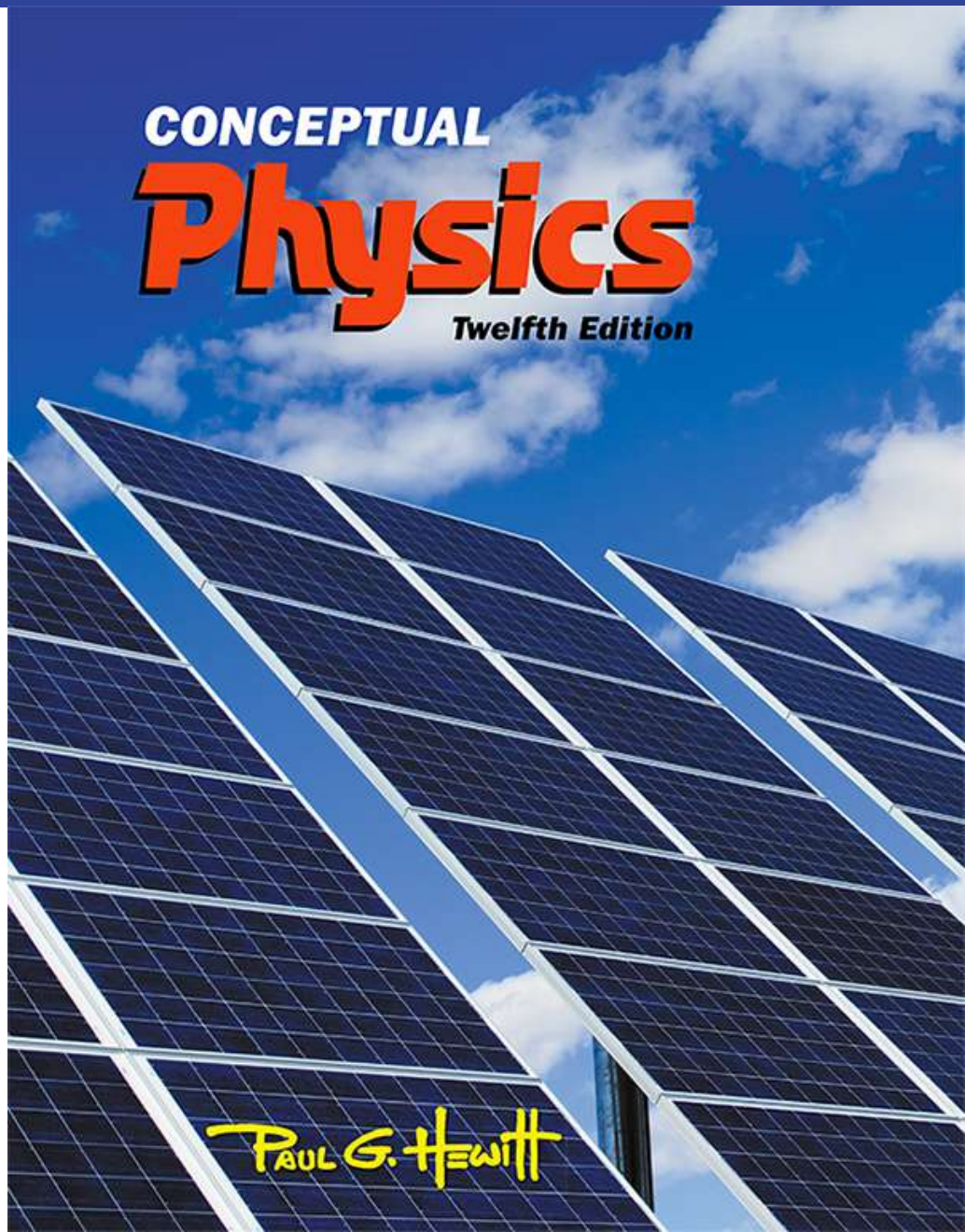
Lecture Outline



Chapter 19: Vibrations And Waves

Part 1

Good Vibrations

A *vibration* is a periodic wiggle in **time**.

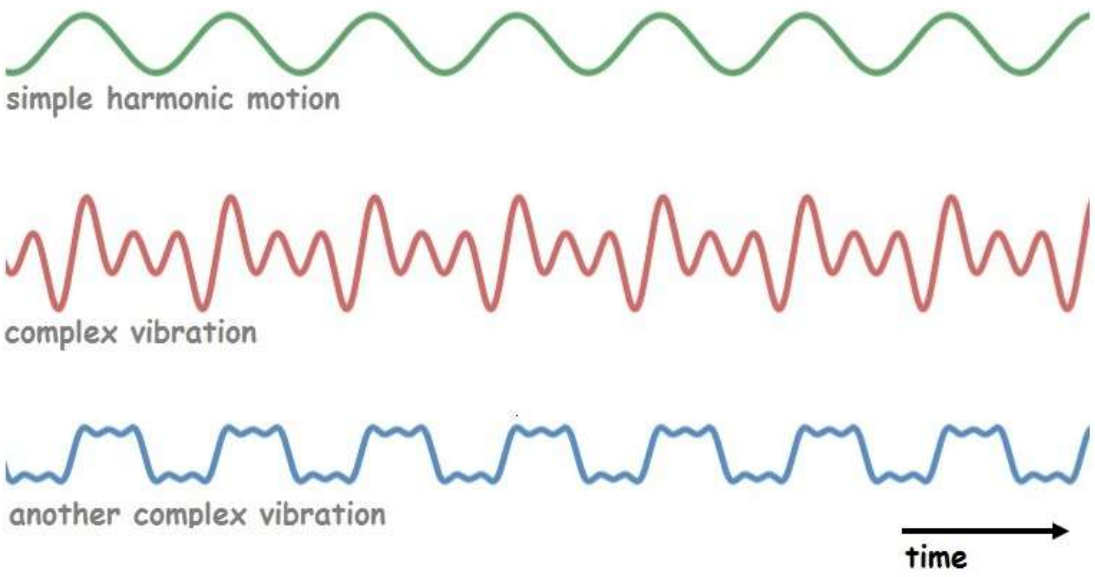
Examples:

Your vocal chords, musical instruments

Computer and cell phone signals

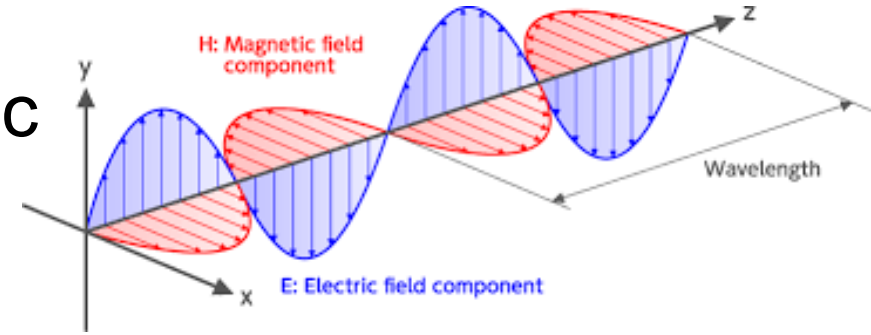
Buildings, bridges, etc.

Sketched:

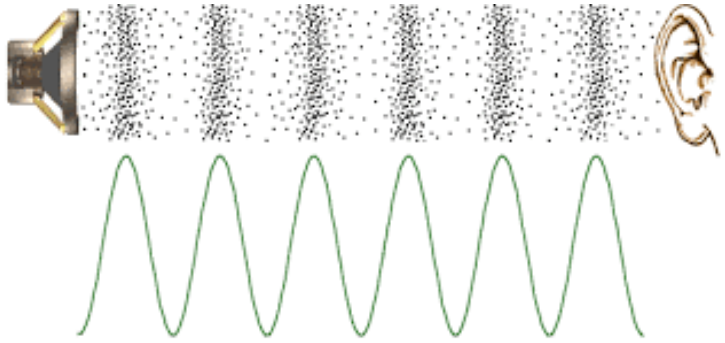


- A wave: a periodic wiggle in both space and time
- A wave extends from one place to another.
- *The medium* (pl *media*) = what wave moves through

- Examples of waves:
  - **light** is an electromagnetic wave that requires no medium.

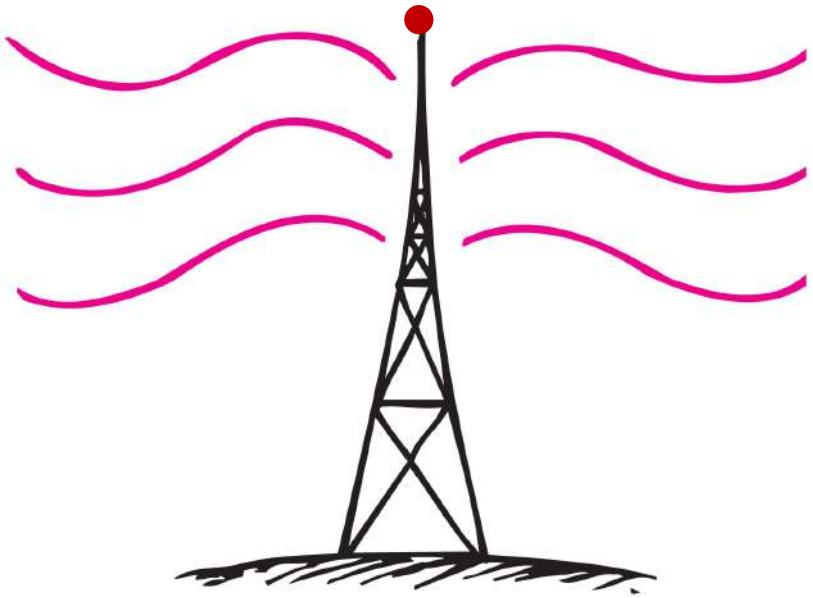


  - **sound** is a mechanical (particles actually move) wave that needs a medium (air, water, solids).



Vibrations and Waves

- Vibration:
  - Wiggle in time
- Wave:
  - Wiggle in space and time



- Electrons in an antenna vibrate up and down.
- The accelerating electrons cause electromagnetic waves that travel through the atmosphere (the medium) or through a vacuum (no air).
- Waves are caused by vibrations.

Vibration, Wave and Media

During an earthquake, the Earth vibrates up and down.

This causes earthquake waves that travel in the ground

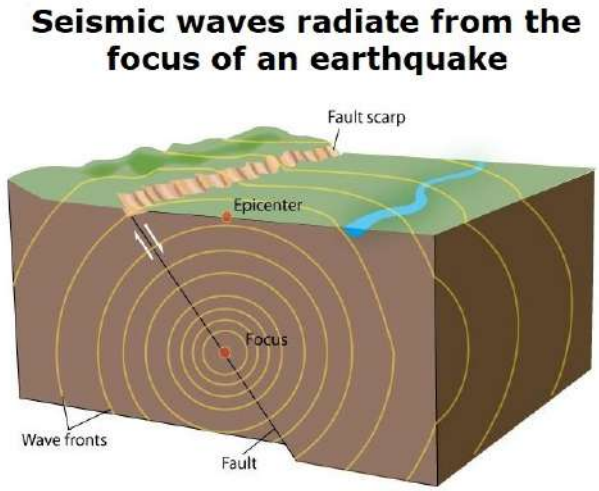
The ground is the medium.

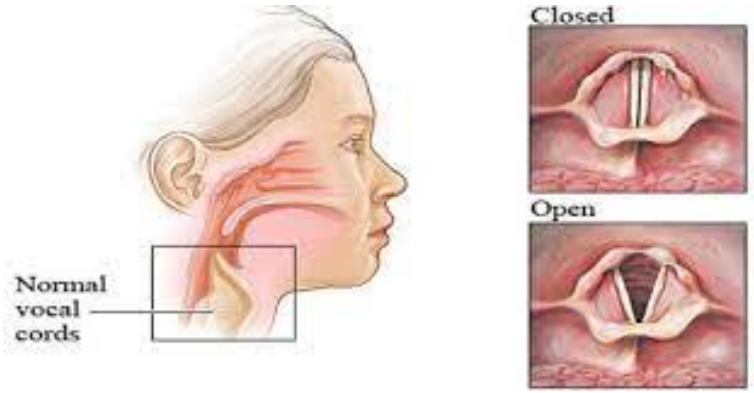
When you talk, your vocal chords vibrate back and forth.

This causes sound waves to travel through the air.

The air is the medium.

Waves are caused by vibrations.





Classwork: New sheet of paper

1. What is a *wiggle in time* called? What do you call a *wiggle in space* and time?

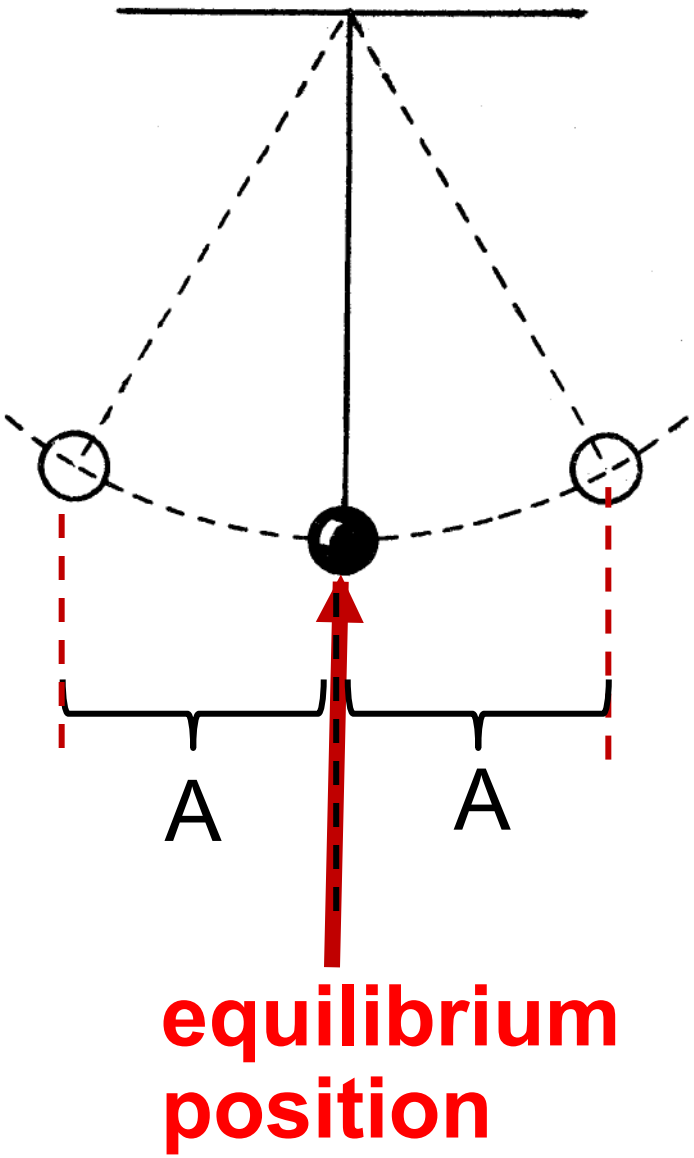
2. What is the source of all waves?

Pendulum

If we suspend a stone (the *bob*) at the end of a piece of string, we have a simple pendulum.

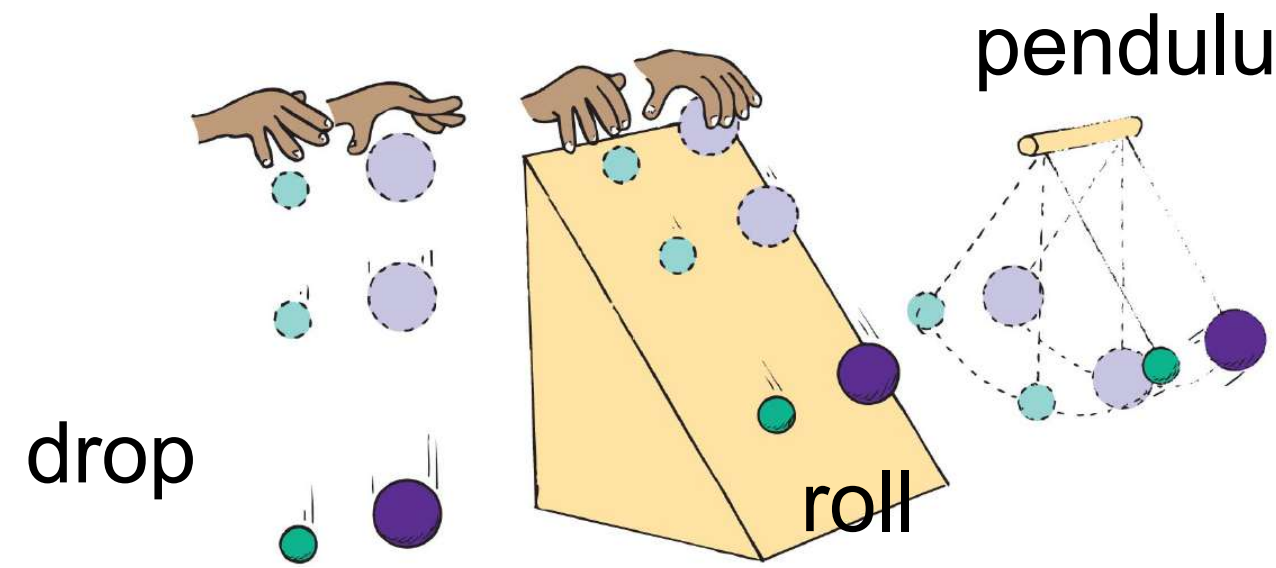
The equilibrium position is the rest or mid-point position.

The amplitude A is the maximum distance that the bob moves from its equilibrium (rest) position.

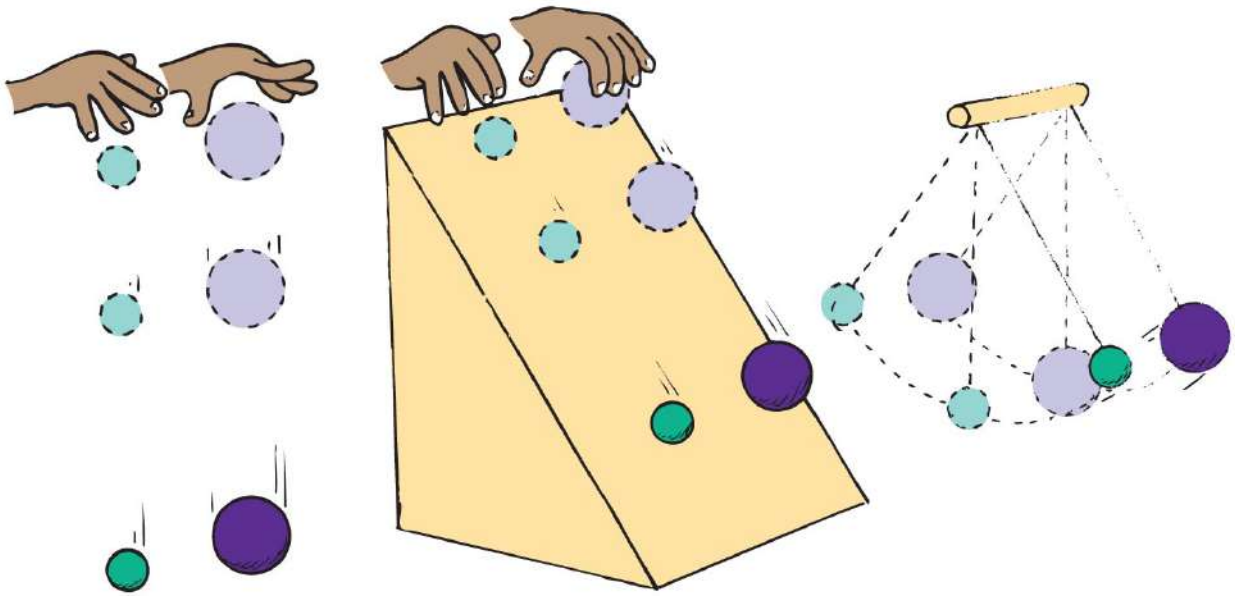


Vibrations of a Pendulum

- The pendulum swings to and fro at a rate that
  - depends only on the *length* of the pendulum.
  - does not depend upon the mass (just as mass does not affect the rate at which a ball falls or rolls to the ground).



- The time of one to-and-fro swing is called the **period**.
- The longer the length of a pendulum, the longer the period
- Just as the higher you drop a ball from, the longer it takes to reach the ground.



Vibrations of a Pendulum
CHECK YOUR NEIGHBOR

A 1-meter-long pendulum has a bob with a mass of 1 kg. Suppose that the bob is now replaced with a different bob of mass 2 kg, how will the period of the pendulum change?

A. It will double.
B. It will halve.
C. It will remain the same.
D. There is not enough information.

Vibrations of a Pendulum
CHECK YOUR ANSWER

A 1-meter-long pendulum has a bob with a mass of 1 kg. Suppose that the bob is now replaced with a different bob of mass 2 kg, how will the period of the pendulum change?

C. It will remain the same.

Explanation:
The period of a pendulum depends only on the length of the pendulum, not on the mass. So changing the mass will not change the period of the pendulum.

Vibrations of a Pendulum
CHECK YOUR NEIGHBOR, Continued

A 1-meter-long pendulum has a bob with a mass of 1 kg. Suppose that the bob is now tied to a different string so that the length of the pendulum is now 2 m. How will the period of the pendulum change?

A. It will increase.
B. It will decrease.
C. It will remain the same.
D. There is not enough information.

Vibrations of a Pendulum
CHECK YOUR ANSWER, Continued

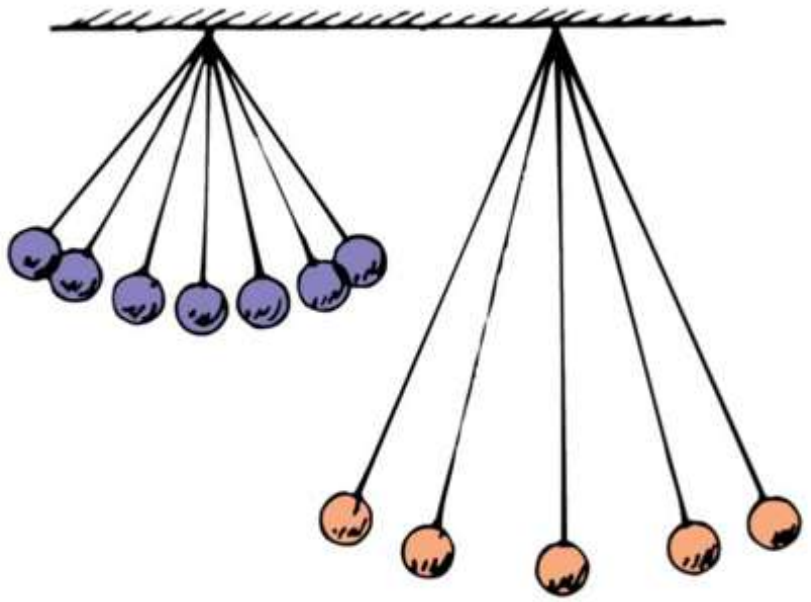
A 1-meter-long pendulum has a bob with a mass of 1 kg. Suppose that the bob is now tied to a different string so that the length of the pendulum is now 2 m. How will the period of the pendulum change?

A. It will increase.

Explanation:
The period of a pendulum increases with the length of the pendulum.

Longer string → more rotational inertia

The short pendulum will swing back and forth more frequently than the long pendulum.



Rotational inertial depends on the distance that the mass if from its point of rotation

→ more distance
→ more rotational inertia
→ harder to vibrate
→ longer period

Grandfather clock:

falling weights provide the energy that is lost to friction in pendulum

pendulum keeps time

A metronome is an upside down pendulum.

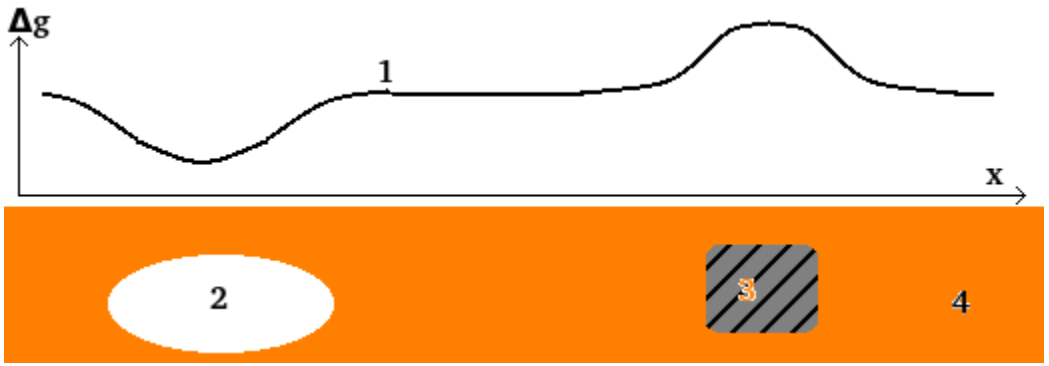
Equation for the period T of a pendulum:

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

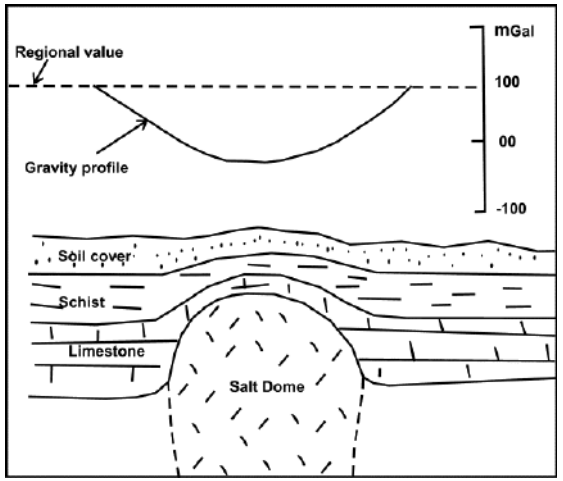
L = length of pendulum

g = acceleration due to gravity

A pendulum can be used to measure g.
This can reveal how dense the rock under you is.
Prospectors use this to find iron (higher density) or oil (lower density).



salt iron



trapped oil

Classwork (continued)

3. What is meant by the *period* of a pendulum?

4. Which has the longer period: a short or a long pendulum?

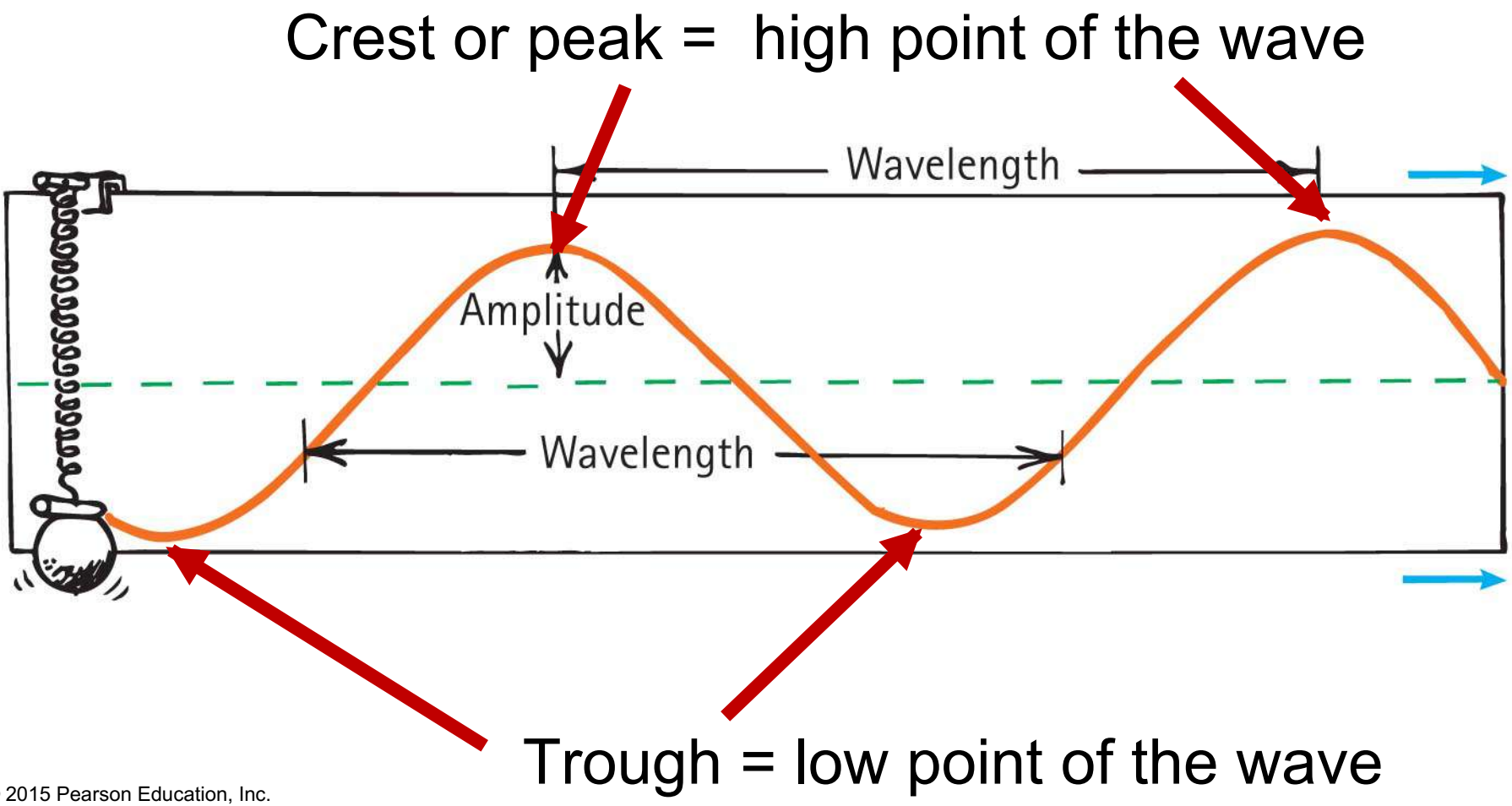
Wave Description

- A wave is pictorially represented by a *sine curve*. It is obtained when you trace out the path of a vibrating pendulum over time.
  - Put some sand in the pendulum and let it swing.
  - The sand drops through a hole in the pendulum onto a sheet of paper. As the pendulum swings back and forth, pull the sheet of paper on which the sand falls. The sand makes a sine curve on the paper.
  - *The sine wave shows how the amplitude of a vibration or a wave changes in time.*

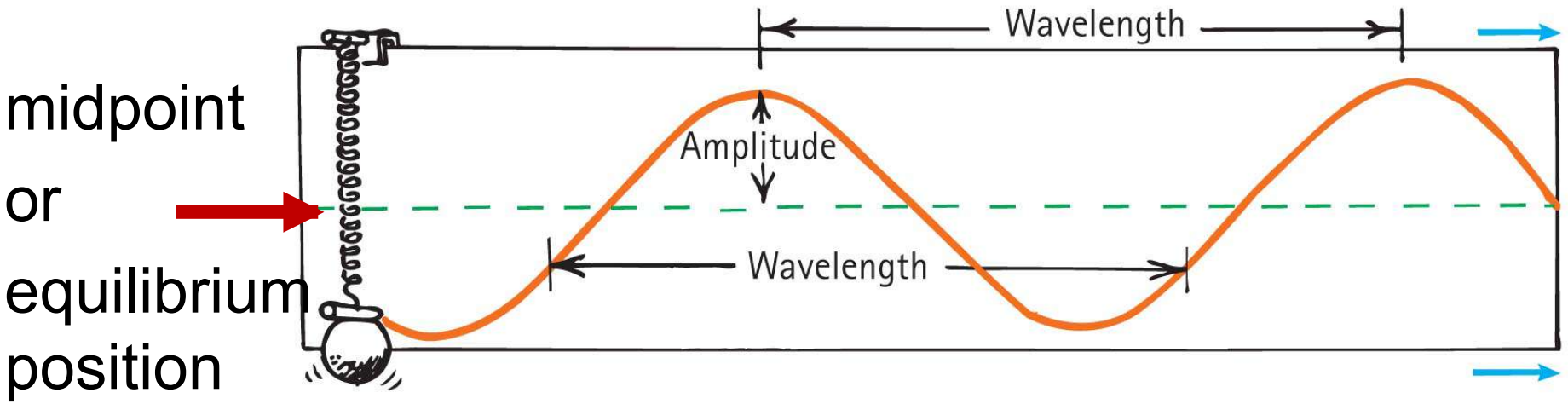
Classwork

5. How does a sine curve relate to the wave description?

- When a bob vibrates up and down, a marking pen traces out a sine curve on the paper that moves horizontally at constant speed.

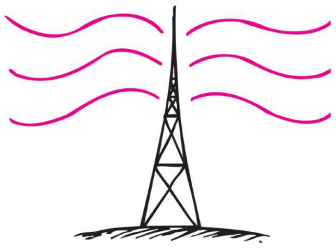


- Vibration and wave characteristics (continued)
  - **Amplitude**
    - distance from the equilibrium position (midpoint) to the crest or to the trough
  - **Wavelength**
    - distance from the top of one crest to the top of the next crest, or distance between successive identical parts of the wave



- Frequency
  - Specifies the number of to and fro (back and forth) vibrations in a given time
  - Number of waves passing any point per second
  - *Examples:*
  - 2 vibrations occurring in 1 second is a frequency of 2 vibrations per second.
  - 5 waves passing a point in 1 second is a frequency of 5 waves per second.
  - 10 waves passing a point in 2 seconds is also a frequency of 5 waves per second.

- **frequency =** how frequently a vibration occurs
- The unit for frequency is *hertz* (Hz).
  - A frequency of 1 Hz is a vibration of any type that occurs once each second.
  - 1 Hz = $\frac{1\ vibration}{sec} = \frac{1\ wave}{sec} = \frac{1\ cycle}{sec} = \frac{1}{sec}$
  - Mechanical objects (e.g., pendulums) have frequencies of a few Hz.
  - Sound has a frequency of a few 100 or 1000 Hz (kHz).
  - Radio waves have frequencies of a few million Hz (MHz).



Classwork (continued):

6. Distinguish among these different aspects of a wave: period, amplitude, wavelength, and frequency.

7. How many vibrations per second are represented in a radio wave of 101.7 MHz?

Period and frequency are inverses:

- Period
  - Time to complete one vibration

$$\text{Period} = \frac{1}{\text{frequency}}$$

or, vice versa,

$$\text{Frequency} = \frac{1}{\text{period}}$$

- Example: Pendulum makes 2 vibrations in 1 second. Frequency is 2 Hz. Period of vibration is 1/2 second.

Wave Description
CHECK YOUR NEIGHBOR

A sound wave has a frequency of 500 Hz. What is the period of vibration of the air molecules due to the sound wave?

A. 1 s
B. 0.01 s
C. 0.002 s
D. 0.005 s

Wave Description
CHECK YOUR ANSWER

A sound wave has a frequency of 500 Hz. What is the period of vibration of the air molecules due to the sound wave?

C. 0.002 s

Explanation:

$$\text{Period} = \frac{1}{\text{frequency}}$$

So:

$$\text{Period} = \frac{1}{500\ Hz} = 0.002\ s$$

Wave Description
CHECK YOUR NEIGHBOR, Continued

If the frequency of a particular wave is 20 Hz, its period is

A. 1/20 second.
B. 20 seconds.
C. more than 20 seconds.
D. None of the above.

Wave Description
CHECK YOUR ANSWER, Continued

If the frequency of a particular wave is 20 Hz, its period is

A. 1/20 second.

Explanation:

Note when f = 20 Hz, $T = 1/f$ = 1/(20 Hz) = 1/20 second.

8. How do frequency and period relate to each other?