SPH3U UNIVERSITY PHYSICS

WAVES & SOUND

- Wave Characteristics (P.385-387)

Wave Characteristics

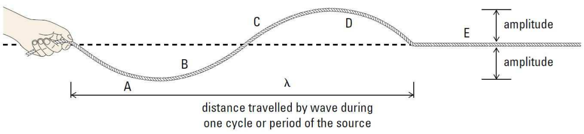
Some characteristics of waves, such as the large water wave shown, are based on geometric features, and some characteristics of waves are based on time. So waves can be described in terms of their size, their shape, and the speed at which they move.

Geometric Wave Characteristics

Wave characteristics based on shape and size (i.e. geometric characteristics) include amplitude, wavelength, phase and phase shift.

Geometric Wave Characteristics

The maximum displacement of a vibrating particle in a wave from its equilibrium point is called the ***amplitude****. The maximum point in a transverse wave is called a* ***crest****, and the minimum point in a transverse wave is called a* ***trough****.*



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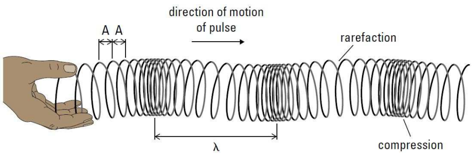
Geometric Wave Characteristics

In a longitudinal wave, the regions where the particles are closer together than normal are called ***compressions****; the regions where they are farther apart are called* ***rarefactions****. The most common longitudinal waves are sound.*



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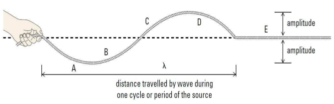
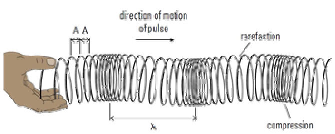
Geometric Wave Characteristics

A continuous wave has many repeating crests and troughs (or compressions and rarefactions). ***Wavelength (λ)*** *is the distance between two similar points in successive identical cycles in a wave (such as from crest to crest in the case of a transverse wave or from compression to compression in the case of a longitudinal wave).*





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Geometric Wave Characteristics

PRACTICE

1. Sketch a periodic wave consisting of two complete wavelengths, each with λ = 4.0 cm. Label the diagram with amplitude, crest, trough, wavelength, and equilibrium (or rest) position.

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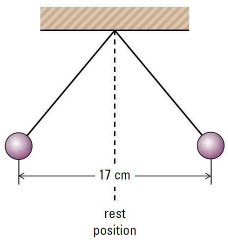
Geometric Wave Characteristics

PRACTICE

2. For the pendulum shown, state:
   (a) the type of vibration
   (b) the amplitude
   (c) the total distance the mass moves horizontally in five cycles



   (a) transverse
   (b) A = 8.5 cm
   (c) d = 170 cm

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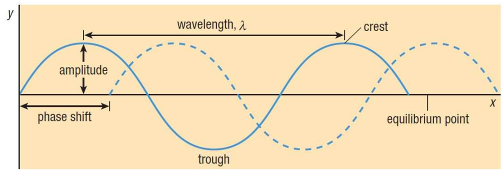
Geometric Wave Characteristics

NOTE!

Two waves can be identical to each other but shifted along the x-axis with respect to each other. A ***phase shift*** *is a shift of an entire wave with respect to an identical wave along the x-axis, usually by some fraction of a single wavelength.* *<u>This is a very important concept in electricity, electronics, the physics of sound, and the study of the atom</u>.*



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Time-Based Wave Characteristics

Time-based wave characteristics are related to the motion of the vibrating particle and the wave. These characteristics are frequency, period, and the speed at which a wave travels.

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Time-Based Wave Characteristics

The ***frequency (f)*** *of a wave is defined as the number of complete cycles per unit of time (usually 1 s). The SI unit to measure frequency is the* ***hertz (Hz)****, named after Heinrich Hertz, the German scientist who first produced electromagnetic waves in the laboratory.*

$$frequency = \frac{number\ of\ cycles}{total\ time}$$

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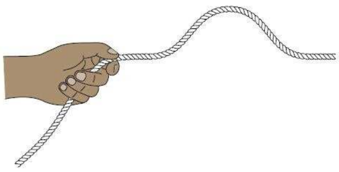
Time-Based Wave Characteristics

NOTE!

The frequency of the wave is exactly the same as that of the source. It is the source alone that determines the frequency of the wave. Once the wave is produced, the frequency never changes, even it its speed and wavelength do change. This behaviour is characteristic of all waves.



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Time-Based Wave Characteristics

*Another term used in describing motion 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 the rotation of the Moon, the day (d) or the year (yr) is used.*

$$period = \frac{total\ time}{number\ of\ cycles}$$

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Time-Based Wave Characteristics

FREQUENCY (f)
- number of cycles per second
- SI unit ☞ hertz (Hz or s^{-1})

PERIOD (T)
- time required for one cycle
- SI unit ☞ second (s)

$$f = \frac{N}{t} \quad \& \quad T = \frac{t}{N}$$

where N is the number of cycles
t is the total time for N cycles (s)

NOTE!
- Frequency and period are reciprocals ☞ f = 1/T & T = 1/f
- The frequency of a wave is the same as that of the source – it is **not** affected by changes in the speed or wavelength of the wave.

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Time-Based Wave Characteristics

PRACTICE

3. A mass attached to the end of a spring vibrates 15 times in 12 s. Calculate (a) the frequency and (b) the period of the vibration.

(a) f = 1.2 Hz
(b) T = 0.80 s

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Time-Based Wave Characteristics

PRACTICE

4. Calculate the frequency of a CD player if it rotates 4.5 x 10^3 times in 1.0 minute.

   f = 75 Hz

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Time-Based Wave Characteristics

PRACTICE

5. If the Moon orbits the Earth six times in 163.8 d, what is its period of revolution?

   T = 27.30 d

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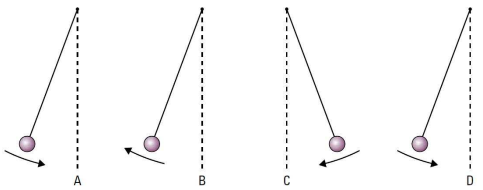
Wave Characteristics

NOTE!

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 – otherwise they are vibrating* ***out of phase****.*



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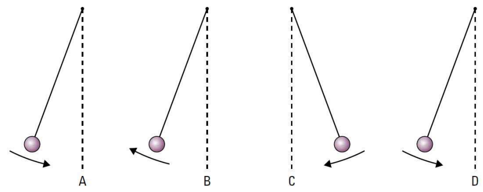
Wave Characteristics

PRACTICE

6. Which pair of pendulums are vibrating in phase?

A & D

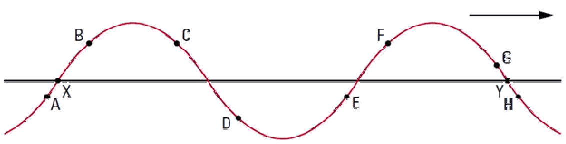


Wave Characteristics

PRACTICE

7. List all pairs of points that are vibrating in phase.

AE & BF



Wave Characteristics

PRACTICE

8. As you walk, describe the movement of your arms and legs as in phase or out of phase oscillations.

	Left Arm	Right Arm
Left Leg	out of phase	in phase
Right Leg	in phase	out of phase

Activity: The Pendulum

INSTRUCTIONS

A. Set up a data table like the one below (recall: f = N/t).

length L (cm)	mass m (g)	amplitude A (cm)	time for 10 cycles t (s)	frequency f (Hz)
100	100	10		
		20		
		30		
100	50	10		
	100			
	200			
100	100	10		
80				
60				
40				
20				

Activity: The Pendulum

INSTRUCTIONS

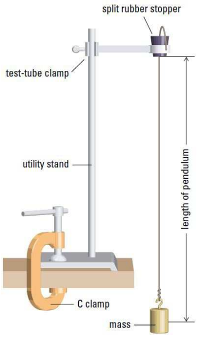
B. Set up the utility stand as illustrated.

C. Obtain a string ~ 110 cm long and attach a 200 g mass to one end. Place the other end of the string into the rubber stopper.

D. Adjust the pendulum length to 100 cm, and clamp the rubber stopper firmly so the string does not slip. The length is measured to the centre of the mass.

E. Pull the mass to one side for an amplitude of 10 cm. Release the mass.

F. Measure the time taken for 10 complete cycles. Repeat once or twice for accuracy. Record this data.



Activity: The Pendulum

INSTRUCTIONS

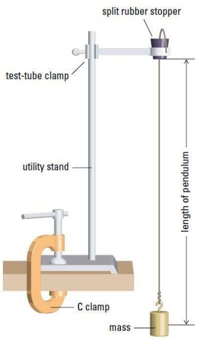
G. Repeat the previous steps using:

(i) a pendulum length of 100 cm, a mass of 100 g, and amplitudes of 20 cm and 30 cm.

(ii) a pendulum length of 100 cm, an amplitude of 10 cm, and 50 g, 100 g, and 200 g masses.

(iii) a mass of 100 g, an amplitude of 10 cm, and pendulum lengths of 100 cm, 80 cm, 60 cm, 40 cm, and 20 cm.

H. Calculate the frequencies for each set of time data. Record your frequency values.

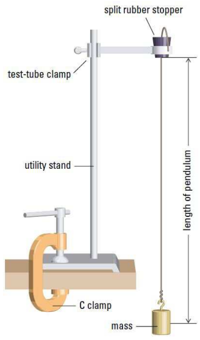


Activity: The Pendulum

QUESTIONS

1. What happened to the frequency of the pendulum when:
   (a) the amplitude increased, but the length and mass remained constant.

   (a) nothing

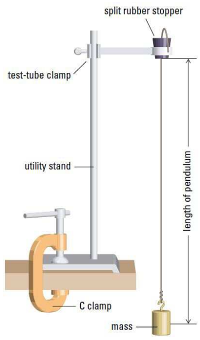


Activity: The Pendulum

QUESTIONS

1. What happened to the frequency of the pendulum when:
   (b) the mass increased, but the length and amplitude remained constant.

   (b) nothing

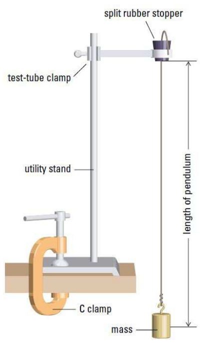


Activity: The Pendulum

QUESTIONS

1. What happened to the frequency of the pendulum when:
   (c) the length increased, but the mass and amplitude remained constant.

   (c) the frequency decreased

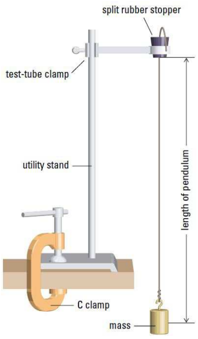


Activity: The Pendulum

QUESTIONS

2. What is the relationship between the frequency of a simple pendulum and its mass, amplitude, and length?

f ∝ 1/L

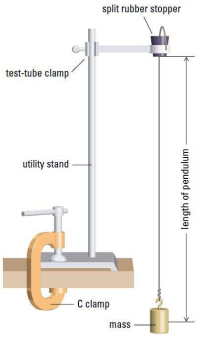


Activity: The Pendulum

QUESTIONS

3. Describe the sources of error in this investigation and evaluate their effect on the results. Suggest one or two improvements to the experimental design.

answers will vary



✔ Check Your Learning

TEXTBOOK

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