Physics 1408/1420 – General Physics 1

Week of October 24th, 2022

Jorge Martinez-Ortiz

Hello Fellow Physicists,

I am Jorge Martinez-Ortiz, the Master Tutor for Physics this semester. To help you on your journey to learn about this wonderful branch of science and the understanding it gives us of the world around us, I will be preparing this resource every week to give you an additional tool to better prepare for your week. I will also be conducting Group Tutoring sessions every week, the information for which will be given below. If you are unable to attend group tutoring, the tutoring center also offers one-on-one tutoring session, so be sure to visit the tutoring center or visit https://baylor.edu/tutoring.

PHY 1408/1420 General Physics 1 Group Tutoring sessions will be held every Monday from 6:30-7:30 pm in the Sid Richardson building basement, Room 75. See you there!

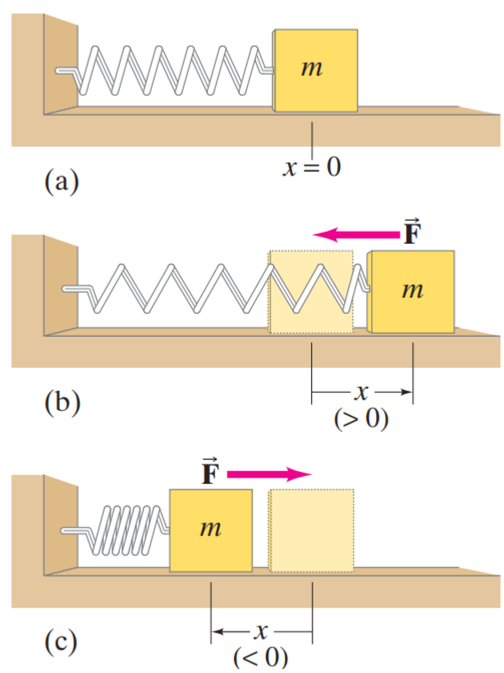
Over the last week, your professors will have covered Fluids. This week, you will explore Oscillations.

Keywords: Simple Harmonic Motion, Wave Motion, Pendulums, Energy in Simple Harmonic Motion

Important Notes
Important Conventions

Simple Harmonic Motion:

Objects that oscillate over the same path in which the oscillation takes the same amount of time is a periodic motion. Objects in simple harmonic motion are in periodic motion with a restoring force pulling back the object to the equilibrium position when the object reaches its maximum displacement. The restoring force is directly proportional to the displacement of the object. The best example that represents simple harmonic motion is an object attached to a spring. The restoring force that pulls on the object is from the spring. When the spring is compressed or stretched, it exerts a force according to



$$F = -kx.$$

The spring has an external force exerted on it when it is stretched or compressed that acts in the opposite direction.

Due to the periodic motion of the object in harmonic motion, there are a few components of the motion that are very important to understand. Amplitude is the maximum displacement from the equilibrium point. Period (T) is the time it takes for one oscillation. Frequency (f) is the number of oscillations that occur in a second. The relation between frequency and period is as follows.

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

Energy in Simple Harmonic Motion

Due to the presence of a spring in the system, the mechanical energy of the system is the sum of the kinetic energy of the object and the potential spring energy of its displacement. Since the object in harmonic motion has an amplitude, its velocity at the amplitude is 0. So the mechanical energy is also equal to the potential spring energy at the amplitude of the oscillation.

$$\tfrac{1}{2}mv^2 + \tfrac{1}{2}kx^2 = \tfrac{1}{2}kA^2.$$

From this equation, the velocity can be derived as a function of the position. We can find the maximum possible and the velocity at a certain position using the following.

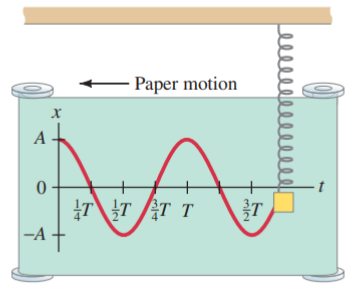
$$v_{\text{max}} = \sqrt{\frac{k}{m}}A \qquad v = \pm v_{\text{max}}\sqrt{1 - \frac{x^2}{A^2}}$$

Sinusoidal Motion:

The mass and the spring constant also affect the period and frequency of oscillation of a simple harmonic oscillator.

$$T = 2\pi\sqrt{\frac{m}{k}}. \qquad f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}.$$

The motion of a simple harmonic oscillator can also be see graphically. The motion forms a sinusoidal curve. The sinusoidal nature of the curve allows us to use functions to analyze the motion of the objects. We can use the following functions to understand the motion of the object in terms of position, velocity, and acceleration. What is most important about this section is to understand what each variable means and how it affects the behavior of the wave.



$$x = A\sin\omega t = A\sin(2\pi t/T)$$

$$v = -v_{max}\sin\omega t = -v_{max}\sin(2\pi f t) = -v_{max}\sin(2\pi t/T).$$

$$v_{max} = 2\pi A f = A\sqrt{\frac{k}{m}}.$$

$$a = \frac{F}{m} = \frac{-kx}{m} = -\left(\frac{kA}{m}\right)\cos\omega t = -a_{max}\cos(2\pi t/T)$$

$$a_{max} = kA/m.$$

Example:

The displacement of an object is described by the following equation, where x is in meters and is in seconds:

$$x = (0.30\,\mathrm{m})\cos(8.0\,t).$$

Determine the oscillating object's amplitude, frequency, period, maximum speed, and maximum acceleration

Solution

From the given function

Amplitude = 0.3 m 2πft = 8, for t = 1 s f = 8/2π f (frequency) = 1.27 Hz

T = 1/f = 1/1.27 = 0.79 s

v_{max} = 2πft = 2π (1.27) (0.3) = 2.4 m/s

a_{max} = Ak/m = $(0.3)(2\pi f)^2$ = $(0.3)(2\pi\,(1.27))^2$ = 19 m/s^2

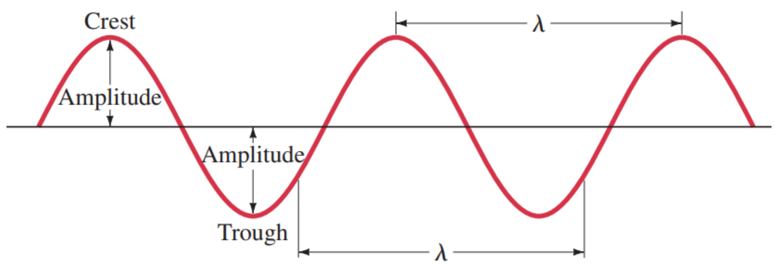
Simple Pendulum

Another system that shows simple harmonic motion is the simple pendulum. Much like the spring system, the simple pendulum is governed by restoring force and a periodic motion. The pendulum is governed by gravity and the equation that governs it is given as follows:

$$F = -mg\sin\theta, \qquad T = 2\pi\sqrt{\frac{\ell}{g}}. \qquad f = \frac{1}{2\pi}\sqrt{\frac{g}{\ell}}.$$

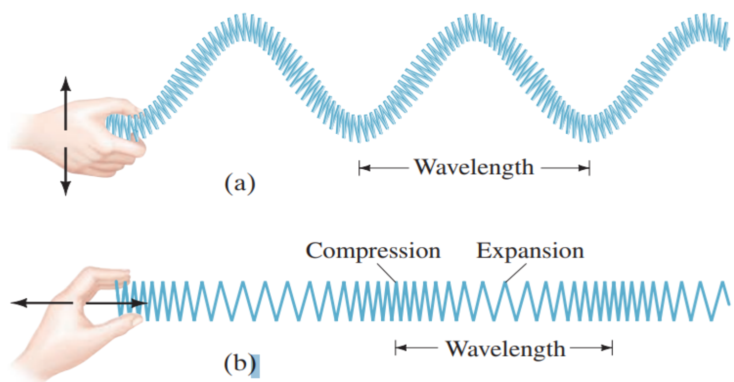
Wave Motion

Mechanical waves are waves that propagate as oscillations in a medium. Waves carry energy. A wave has many different components as shown in the figure. Waves also have a wave speed for each of the crests. The wave speeds can be calculated using the following equation.



v = fλ

There two types of wave motion. A transverse wave motion and a longitudinal wave motion. They look like the following figure. The (a) wave represents a transverse wave and wave (b) represents a longitudnal wave.

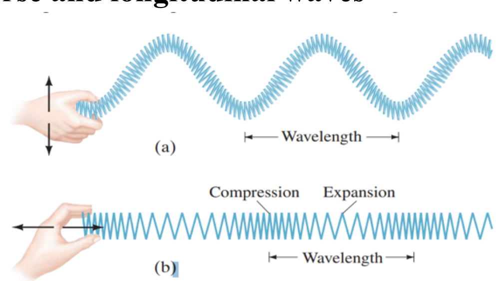


CHECK YOUR LEARNING

1. An elastic cord is 100 cm when a weight of 100 N hangs from it but is 200 cm long when a weight of 200 N hangs from it. What is the spring constant for the cord?
2. It takes a force of 50 N to compress the spring of a toy gun 0.1 m to load a 0.1 kg ball. With what speed will the ball leave the gun?
3. What is the period of a simple pendulum 20 cm long (a) on earth and (b) when it is free falling in an elevator?
4. A soundwave in air has a frequency of 600 Hz and travels at the speed of 343 m/s. How far apart are the wave compressions?

THINGS YOU MAY STRUGGLE WITH

1. **Visualizing oscillations as sinusoidal function**
   Relying on the imagery described in the above text will be the best way to visualize how the oscillations result in the wave graph when you consider position vs time. We use sine and cosine because these functions are periodic, meaning their behavior remains the same for the wave for 2π interval.
2. **Understanding the behavior of energy in oscillations**
   The total energy for the system is the same throughout the motion (conservation of energy!). But the energy is interconverted between kinetic and potential energy during the oscillatory motion. You can use the simple pendulum to visualize this. At the amplitudes, it's all potential energy in the form of gravity, and during the motion of the arc it converts to kinetic when it moves down and back to potential when it moves up.
3. **Understanding the difference between transverse and longitudinal waves**
   When energy is being transported by a wave, each point along the wave oscillates. In a transverse wave, the oscillation is perpendicular to the direction of motion of the wave. When the wave is longitudinal, the change oscillation occurs in the same direction as the direction of motion of the wave.



I hope you have a wonderful week! Please feel free to reach out to me if you have any questions and check out all the resources the Tutoring Center has to offer at: https://baylor.edu/tutoring

Answers: 1. 1000 N/m, 2. 7.07 m/s, 3. 0.897 s, no period, 4. 5.7 m