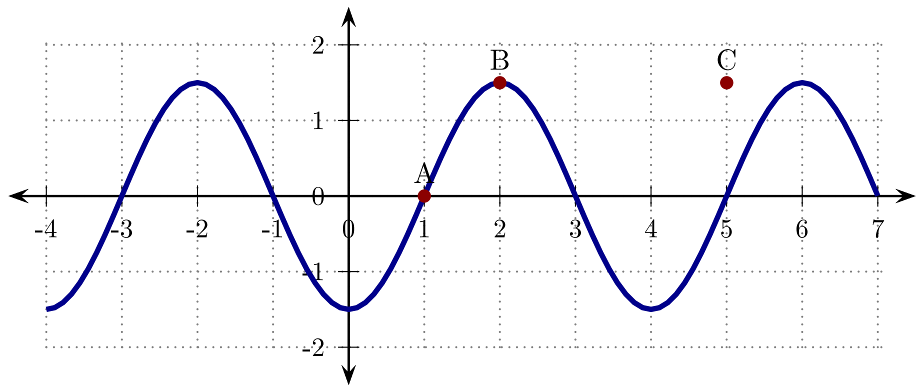
Concepts of Physics: Homework 8

Due: 2 November 2022

1 Continuous waves

A snapshot of a segment of a wave on a string at a particular instant is illustrated. The distances are measured in meters.



The crest labeled B takes 6.0 s to reach point C. For each of the following, explain your answers.

a) Determine the wavelength of the wave.

b) Determine the speed of the wave.

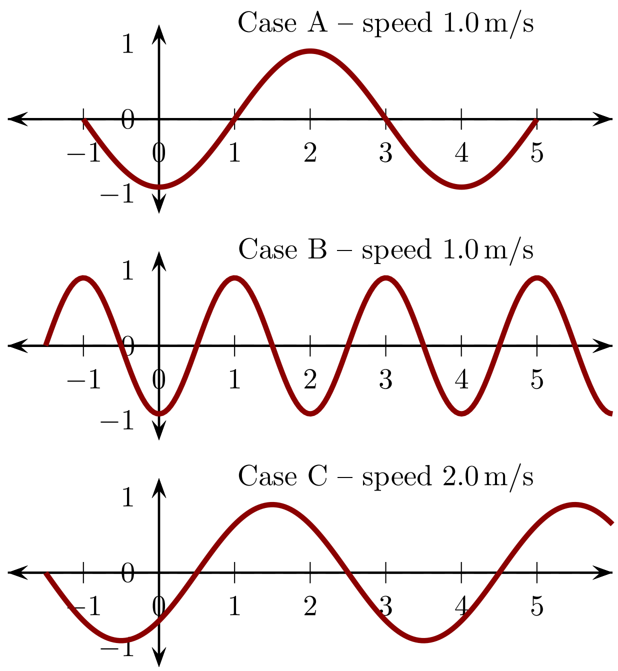
c) How many crests of the wave pass the point B in 4 minutes?

2 Wavelength and frequency

Various waves on strings are as illustrated. The wave speeds are provided for each case. The units of the axes are meters.

a) Rank the waves in order of increasing wavelength. Indicate equality whenever it occurs. Explain your answer.

b) Rank the waves in order of increasing frequency. Indicate equality whenever it occurs. Explain your answer.



3 Waves on a string with an oscillating end

The PhET animation "Waves on a String" allows you to visualize transverse waves on a string. Find the animation at

https://phet.colorado.edu/en/simulation/wave-on-a-string

and open it. Adjust the settings as follows:

- Check the button "No end" at the upper right.
- Check the button "Oscillate" at the upper left.
- In the control panel at the bottom, adjust "Damping" to none.
- In the control panel at the bottom, adjust "Tension" to low.
- In the control panel at the bottom, check the "Rulers" and "Timer" buttons.

a) Set the frequency to 0.30 Hz. Using the rulers and timer, determine the speed of the wave. Using the ruler, determine the wavelength of the wave. Determine the frequency of the wave by counting crests that pass a given point.

b) Set the frequency to 0.60 Hz. Repeat part a).

c) Is the speed the same in both cases?

d) Check that

$$\text{speed} = \text{wavelength} \times \text{frequency}$$

in both cases.

4 Float on water waves

A small fishing float sits in one location on the surface of a pond. Water waves are created on the pond and the float bobs up and down. Alice notices that the float bobs up and down 20 times in 25 s and also that the distance between successive crests of the water waves is 5.0 cm.

a) Determine the frequency of the water waves.

b) Determine the speed of the water waves.

5 GPS signal

GPS works by sending electromagnetic waves from satellites in known locations to GPS receivers (e.g. in a cell phone) on Earth. The satellites orbit at distances of 20200 km above Earth's surface. Consider a GPS satellite that is directly above a receiver on Earth.

a) How long does it take the signal to travel from the satellite to the receiver?

GPS works by recording the time at which several signals were sent from satellites in known locations. With enough such signals one can calculate the time taken for the signal to travel from each satellite to the receiver. These times can then be used to determine how far the receiver is from each satellite and then the receiver location. The following illustrates an artificial example, using a receiver in a space craft, of the accuracy needed in the timing.

b) Suppose that the timer states that it takes a signal to travel from a satellite to a receiver in a space craft is $20\,\mu\text{s} = 0.000020\,\text{s}$. Determine how far the receiver is from the satellite according to this time.

c) Suppose that the timer is inaccurate by $1\,\mu\text{s} = 0.000001\,\text{s}$. Thus the time taken was actually $21\,\mu\text{s} = 0.000021\,\text{s}$. Determine how far the receiver truly is from the satellite. How much error in distance would the inaccurate timing produce?

6 Electromagnetic waves for cell phone communication

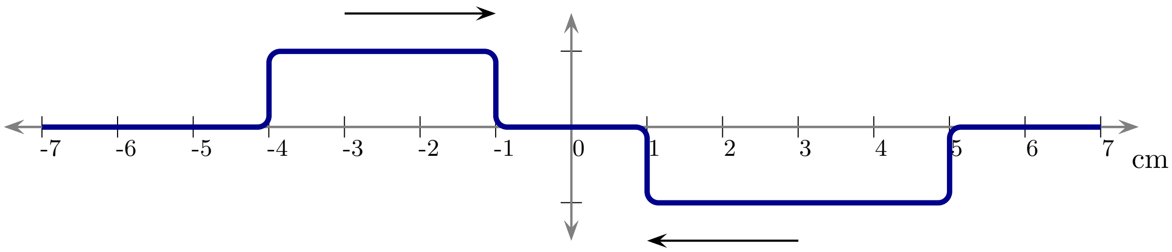
A cell phone communicates by transmitting and receiving electromagnetic waves. These travel at the speed of light, $3.0 \times 10^{8}\,\text{m/s}$. A particular phone uses waves with frequency $900 \times 10^{6}\,\text{Hz}$.

a) Determine the wavelength of these waves.

b) The wavelength is important in the design of the antenna that the cellphone uses to receive and transmit. The antenna is a metal structure built into the device. For various physical reasons the antenna is most sensitive and efficient when its length is about half a wavelength. Determine the optimal length for the antenna in a cellphone that uses the wave described above. Sketch this length on the page. How does it correspond to the dimensions of your cell phone?

7 Interference of waves on a string

Two rectangular wave pulses move along a string with speeds 1 cm/s. Initially the string appears as illustrated.



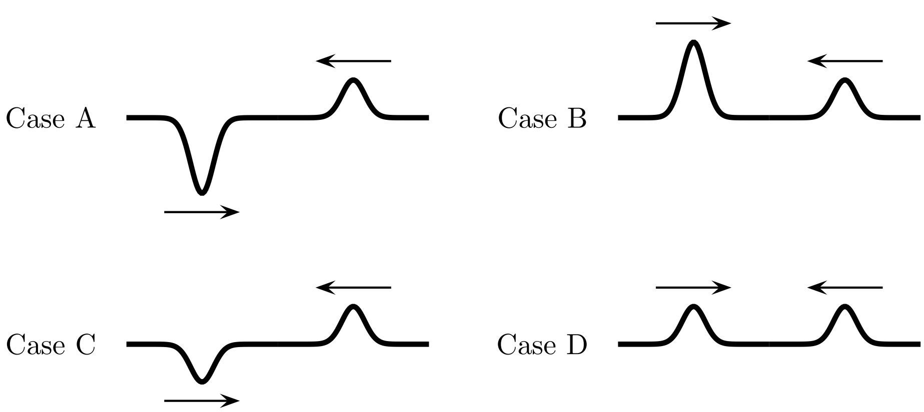
In the following questions the times refer to the time after this instant.

a) Illustrate the appearance of the string after 2 s has passed. Use the axes on the attached sheet to do this.

b) Illustrate the appearance of the string after 3 s has passed. Use the axes on the attached sheet to do this.

8 Interference of pulses

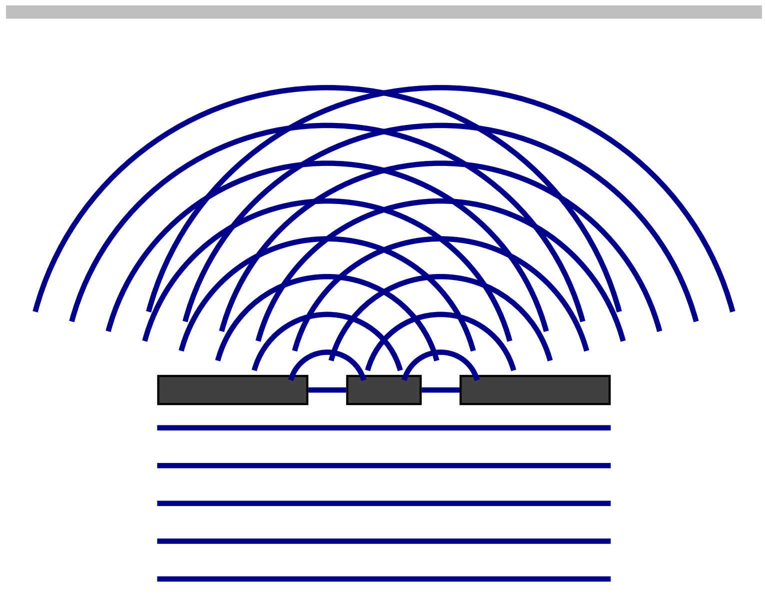
Various pulses approach each other as illustrated.



The pulses overlap and interfere. Rank the situations in order of increasing peak height during interference (indicate any ties in the ranking).

9 Interference from two slits

The following diagram illustrates the crests of circular waves that pass through each of two slits.



a) Indicate the lines along which constructive interference occurs and the points at which bright spots will appear on the screen.

b) Use a similar diagram to indicate the changes in the locations of the bright spots when the wavelength of the light increases. Are they further apart, closer together or do they have the same spacing as a result of the change in wavelength?

10 Reading exercise

Read section 9.3 (pages 193-195). The following exercises are intended to give you an understanding of the concepts presented in the text.

a) Briefly describe, based on the content of this section, how one could demonstrate that light is a wave.

b) Light passes through two slits as illustrated in Fig. 9.16. Suppose that light consisted of particles (think of these as minute solid balls) and that these move at high speed toward the two slits. Illustrate where these would arrive on the screen, given that they obey the usual rules by which balls move. How does this compare to Fig. 9.17.

c) Do Concept Check 5 on page 195. After you have done it check the answer at the end of the text.

d) Do Conceptual Exercise 9 on page 222.