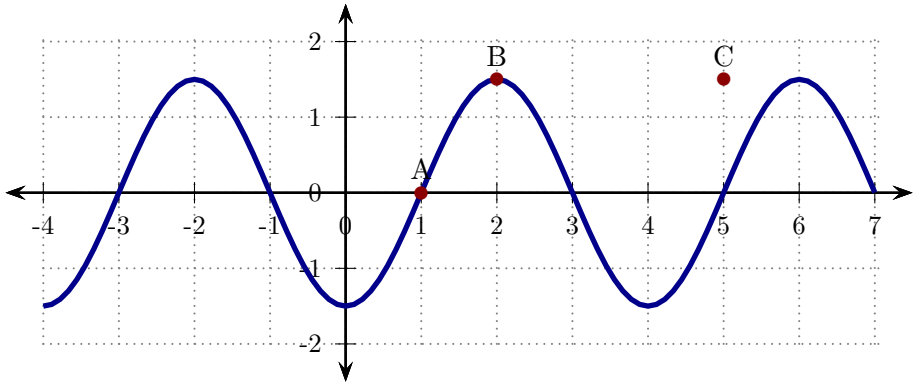
Concepts of Physics: Homework 8

Due: 6 November 2023

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.

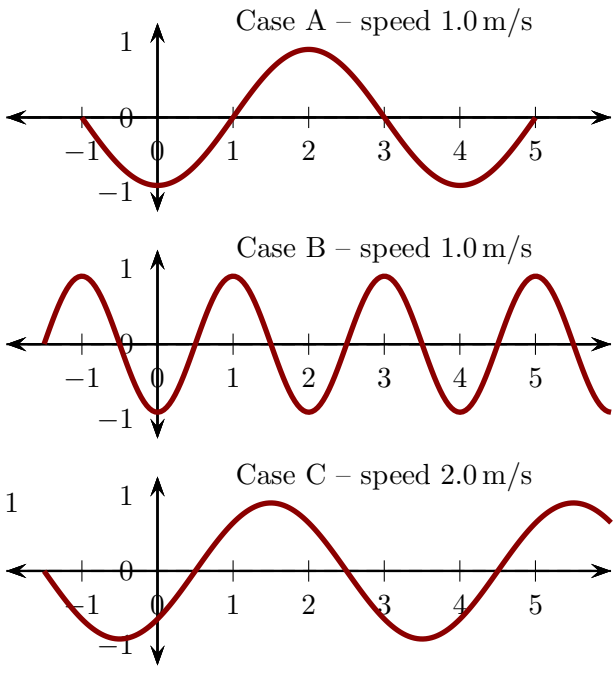
c) How many crests of the wave pass the point B in 4 minutes?

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 an endless string

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. Observe a crest that travels for some amount of time. Using the rulers and timer, measure the distance traveled by a crest, the time taken to do this and use these to determine the speed of the wave.

b) Using the ruler, determine the wavelength of the wave.

c) Determine the frequency of the wave by counting how long it takes five crests to pass a given point. *Do not use speed = wavelength × frequency at this stage.*

d) Set the frequency to 0.60 Hz. Repeat parts a) to c).

e) Is the speed the same in both cases?

f) 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 Reading exercise: interference of waves

Read section 9.2 (pages 190-193). The following exercises are intended to give you an understanding of the concepts presented in the text.

a) Sound consists of waves which are similar to the water waves illustrated in Fig. 9.12. Suppose that two speakers situated close to each produce sound waves that travel outwards and that a listener moves his/hear ear around to the right of the speakers (corresponding to moving up and down along the right edge of Fig. 9.12). What would the listener observe (i.e. hear)?

b) Do Concept Check 4 on page 191. After you have done it check the answer at the end of the text.

c) Do Conceptual Exercise 9 on page 222.