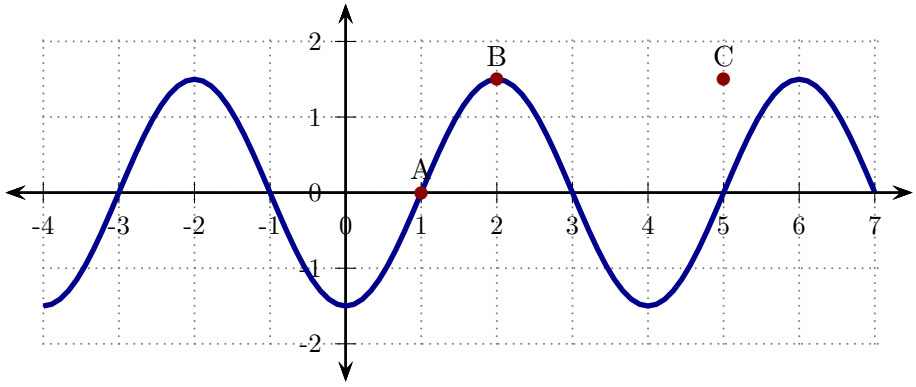
Concepts of Physics: Homework 8

Due: 4 November 2024

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.

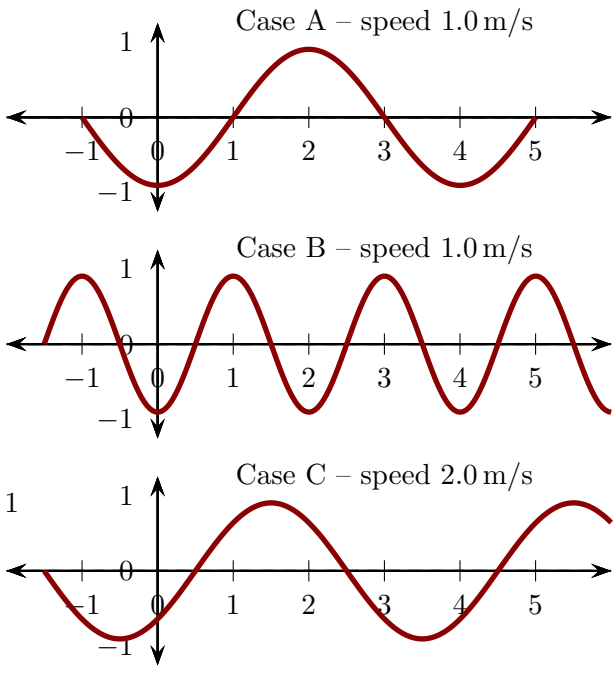
c) How many crests of the wave pass the point B in 4 minutes?

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) Are the speeds the same (or close to the same) in both cases?

f) Calculate the right-hand side of

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

in both cases; i.e. calculate

$$\text{wavelength} \times \text{frequency}.$$

Does the result match the speeds from parts parts (a) and (d)?

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 60 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.

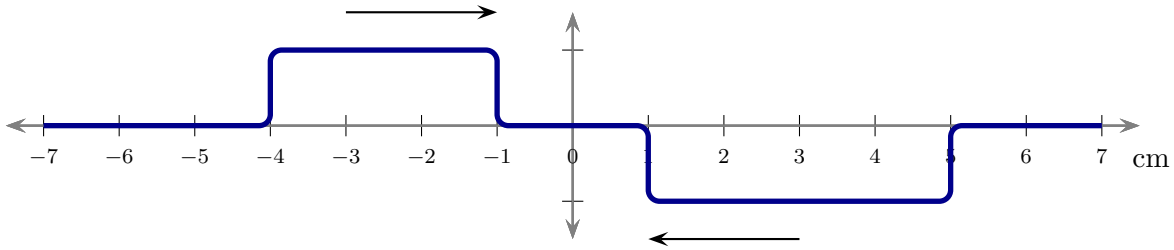
b) Suppose that the timer states that it takes a signal to travel from a satellite to a receiver in a space craft is $20\,\mu\text{s} = 0.000020\,\text{s}$. Determine how far the receiver is from the satellite according to this time.

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?

d) If the clocks involved in the GPS timer were only accurate to 0.001 s, would this be accurate enough for you to effectively use teh GPS in your daily life? Explain your answer.

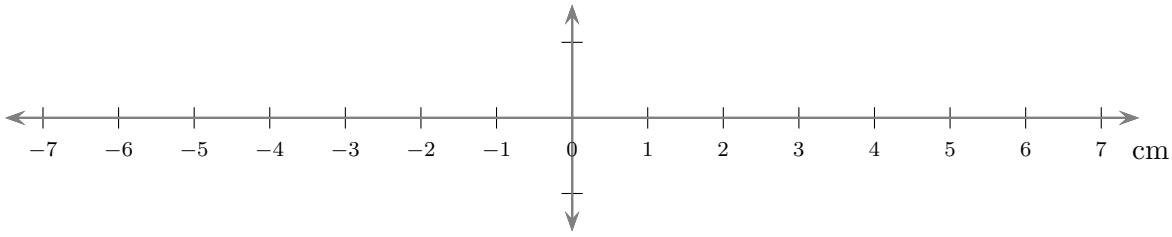
6 Interference of waves on a string

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

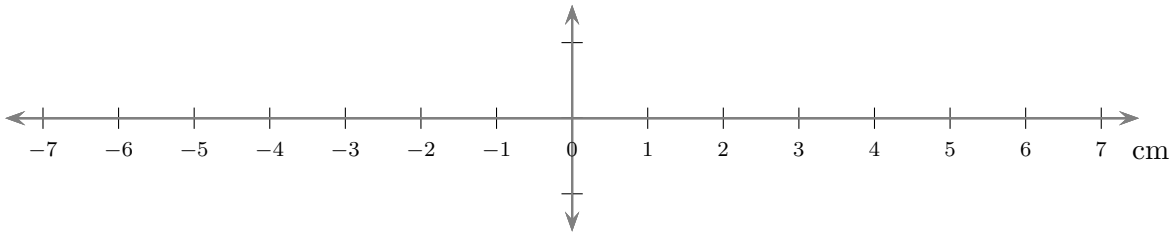


In the following questions the times refer to the time after this instant.

a) Illustrate the appearance of the string after 2 s has passed. Use the axes below to do this. Explain your answer.

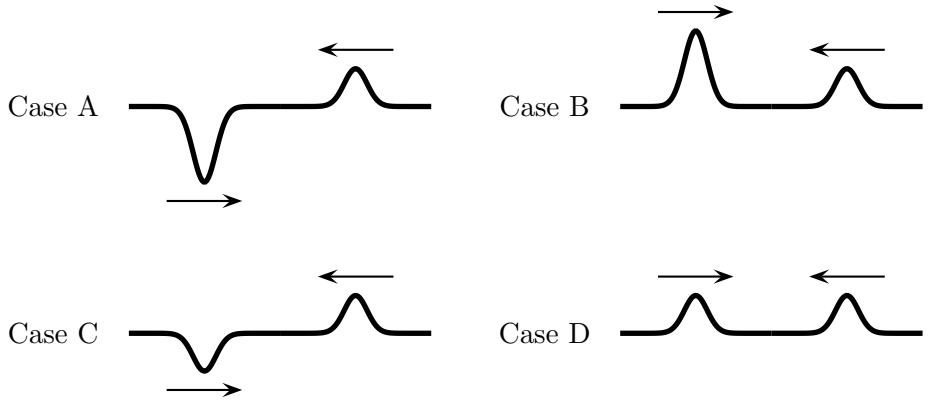


b) Illustrate the appearance of the string after 3 s has passed. Use the axes on the attached sheet to do this. Explain your answer.



7 Interference of pulses

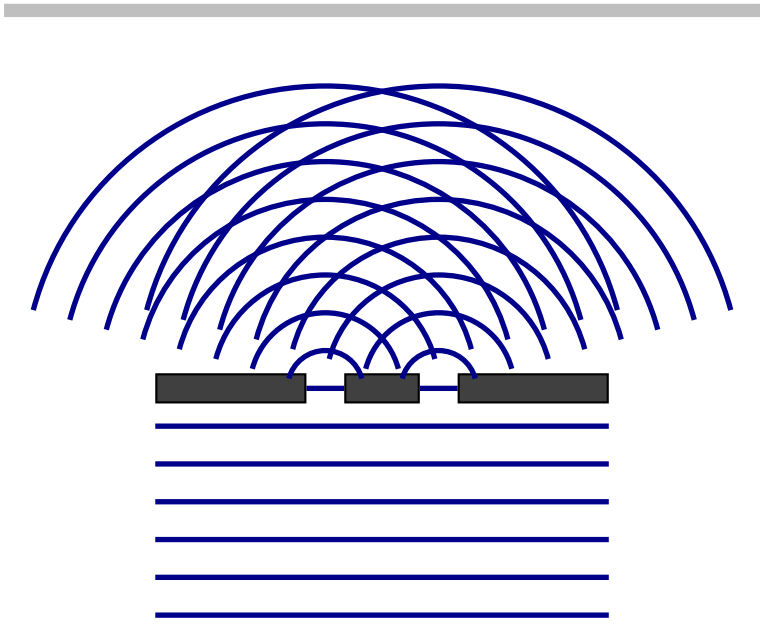
Various pulses approach each other as illustrated. The pulses overlap and interfere; when each does so there will be a point of maximum displacement away from the horizontal.



Rank the situations in order of increasing maximum displacement away from the horizontal during interference (indicate any ties in the ranking). Explain your answer.

8 Interference from two slits

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

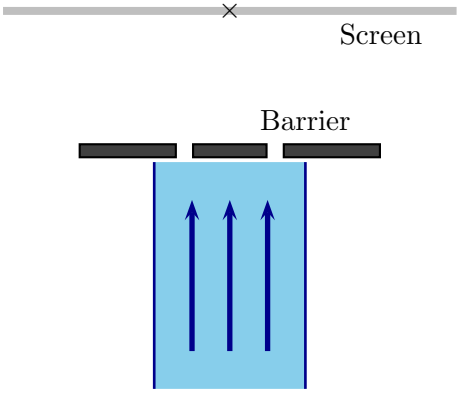


a) Indicate the lines along which constructive interference occurs and the points at which bright spots will appear on the screen.

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?

9 Light passing through two slits: competing models

Consider light that arrives at a barrier with two slits. The intensity of the light could be observed at the point on the screen (×) directly opposite to the midpoint of the barrier and slit arrangement.



a) Consider a model of light in which light consists of small particles that travel in straight lines. What would this model predict for the intensity that would be observed at the marked point on the screen? Explain your answer.

b) Consider a model of light in which light consists waves. What would this model predict for the intensity that would be observed at the marked point on the screen? Explain your answer.

c) Explain *how* you could use such a barrier and slit arrangement to decide which model of light is correct. *Note: you do not need to say which is known to be correct. You do need to provide a procedure (list of steps) that you could use to check. You need to state what the possible results of the procedure are and how you would use these to decide which model is correct.*

10 Interference with different colors of light

The PhET animation "Wave Interference" allows you to visualize interference of waves. Find the animation at

https://phet.colorado.edu/en/simulations/wave-interference

and open it. Adjust the settings as follows:

Select "Slits."

Select the light icon on the right (looks like a small laser pointer).

Select "Two Slits."

Select "Screen."

a) Adjust the frequency of the light into the red. Hit the green button and observe the pattern on the screen.

b) Adjust the frequency of the light into the blue. Hit the green button and observe the pattern on the screen. Are the dark bands on teh screen closer or further apart than for the red light?

c) What does the pattern on the screen tell you (same, smaller, larger) about the wavelength of the blue versus red light? Explain your answer.