

At the end of this worksheet, you should be able to

- use the properties of waves to solve for an unknown quantity.
- use the mathematical description of a wave to plot waves motion over time.
- use the conditions of a standing wave on a string to solve for an unknown quantity.

1. The speed of a wave on a string is proportional to the square root of the tension  $F_T$  in the string and the length  $L$ , and inversely proportional to the square root the mass  $m$  of the string.

a) By what factor does the velocity of the wave change if the *tension doubles*?

b) By what factor does the velocity of the wave change if the *mass triples*?

c) By what factor does the velocity of the wave change if the *length halves (same mass)*?

d) By what factor does the velocity of the wave change if the *mass density doubles*?

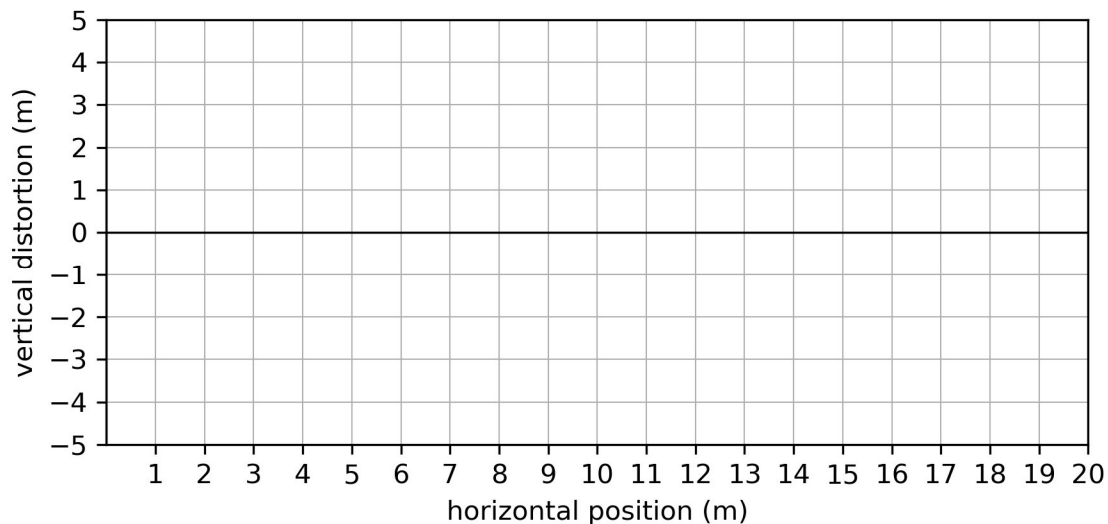
e) If the force doubles and the length triples, by what factor does the velocity change?

- f) By what factor does the force need to change to double the velocity?
- g) By what factor does the mass density need to change to double the velocity?
- h) If the velocity doubles and the mass density halves, by what factor does the force need to change?
2. A string is 2 m long and has a mass of 10 g.
- a) What is its mass density?
- b) The string is cut in half, what is its new mass density?
- c) A force of 10 N is given to the string, what will be the velocity of waves on the string?
- d) What would the force need to be to make the velocity 100 m/s?

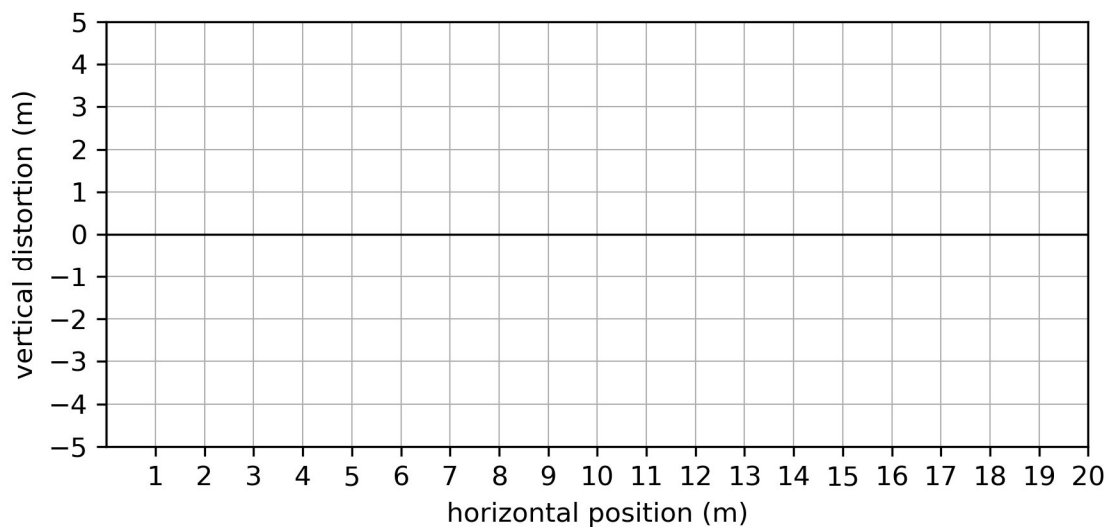
3. A string with a mass density of  $10\text{g/m}$  has a tension of  $100\text{ N}$ . A wave with a period of  $0.1\text{ s}$  is created on the string.
  - a) What is the frequency?
  - b) What is the wavelength of this wave?
  - c) What is the angular frequency and what is the wavenumber?
4. The wavenumber of a wave is  $20\text{ rad/meter}$ , and the period is  $0.1\text{ seconds}$ .
  - a) What is the frequency, angular frequency, wavelength, and velocity?
  - b) The force on the string is  $100\text{N}$ . What is the linear mass density of the string?

- c) If the string is 10 grams, then what is the length of the string?
5. A 1-meter string with a linear mass density of  $10\text{g/m}$  is attached to a wave generator, strung over a pulley, and attached to a 1-kg mass that hangs over the edge of a table (like the lab setup). What is the speed of waves on this string?
6. An identical string (1 meter,  $10\text{ g/m}$ ) hangs vertically from a support with the 1kg mass tied on the end. What is the speed of a wave *near the mass*? What is the speed of a wave *near the top*?

7. A wave has a wavelength of 3 m and an amplitude of 2 m. It travels at a speed of 5 m/s. If the wave has its maximum at the horizontal position of 0 m when  $t = 0$ s, then sketch a plot (snapshot) of the wave at this time below:

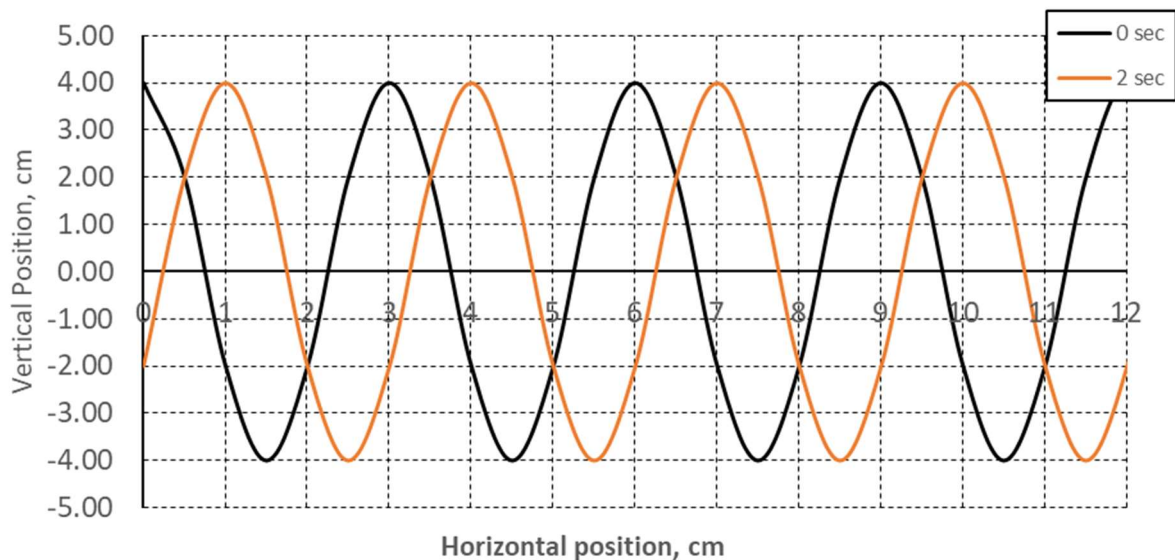


8. Next, sketch the wave after 0.2 seconds have gone by.



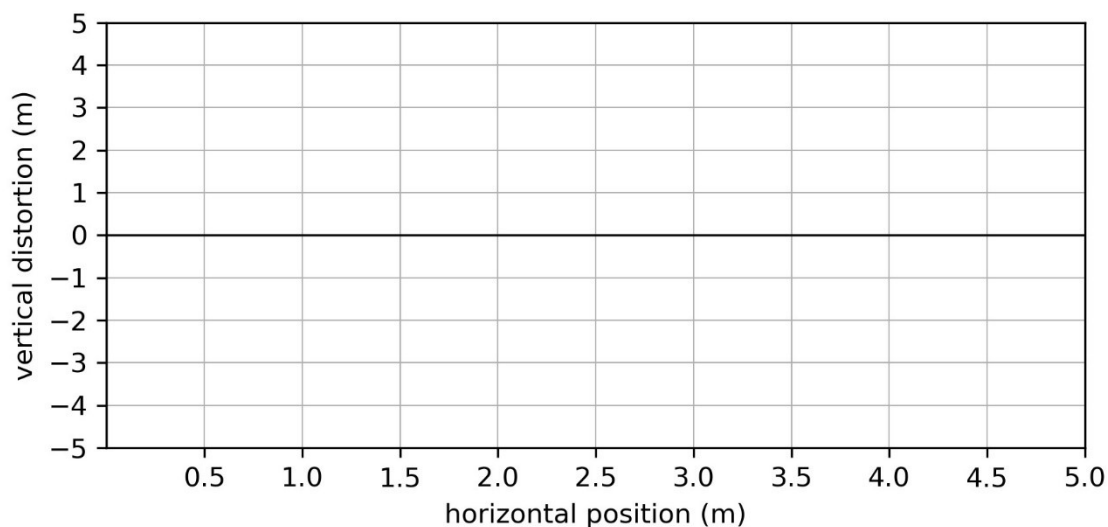
9. Now sketch the wave at  $t = 1.0$  second on the same axis as above.

10. The following plot shows a wave at  $t = 0.0$  s and then later when  $t = 2.0$  s. What is the amplitude, period, angular frequency, wavelength, wavenumber, and velocity?



11. A wave on a string is described by the equation below. Plot this function for  $t = 0$ s and again for  $t = 2.0$ s.

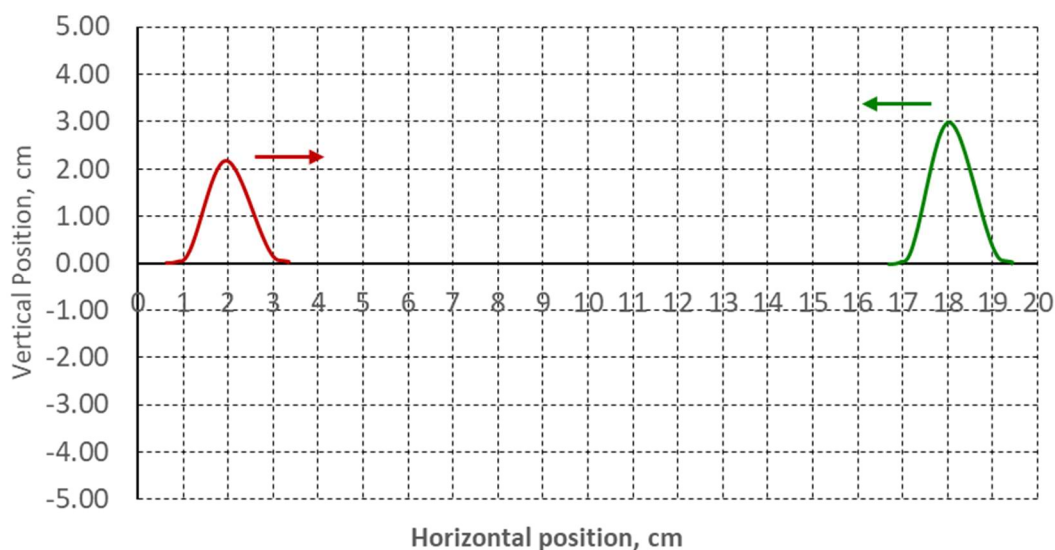
$$y(x,t) = (3.0\text{m})\sin((4\pi\text{ rad/m})x - (8\pi\text{ rad/s})t)$$



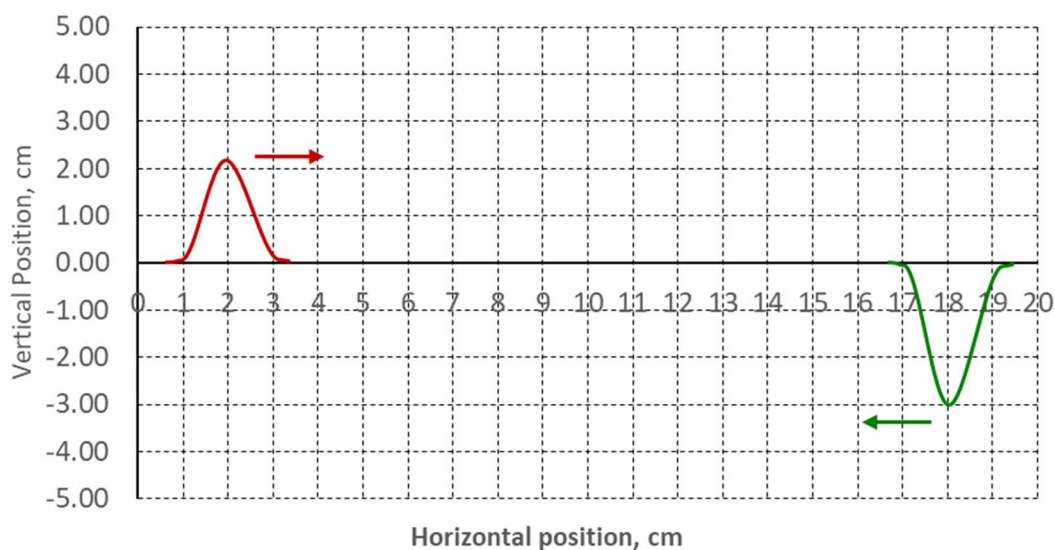
12. Two strings with different linear densities are tied together forming a longer string. One string (String A) has a linear mass density of  $10\text{ g/m}$ ; the other (String B) has a linear density of  $40\text{ g/m}$ . The tension in the string is  $100\text{ N}$ .
- a) What is the velocity of the wave on the first side of the knot?
  
  
  
  
  
  
  
  
  
  
  - b) What is the velocity on the second side?
  
  
  
  
  
  
  
  
  
  
  - c) A wave with a wavelength of  $0.2\text{ meters}$  travels along the string. It originates with String A. What is the frequency of the wave?
  
  
  
  
  
  
  
  
  
  
  - d) A crest of the wave passes through the knot. The velocity of the wave changes when it travels in String B. What else about the wave changes? Frequency or wavelength?
    - In other words, how much time goes by before the next crest passes through the knot? What is the frequency of wave crests coming into the knot? What is the frequency of crests leaving the knot?
  
  
  
  
  
  
    - How far has the first crest traveled in String B? What does this mean about the wavelength on the second side?

- What can you conclude about waves passing through an interface of 2 different materials? When the speed of a wave changes suddenly at an interface does the wavelength change? Does the frequency change? Or do both change?

13. Two waves with the same wavelength approach each other with speed  $v = 4.0$  m/s. At what time and where will these waves fully overlap (their max peaks line up) and what will the wave look like at that time?

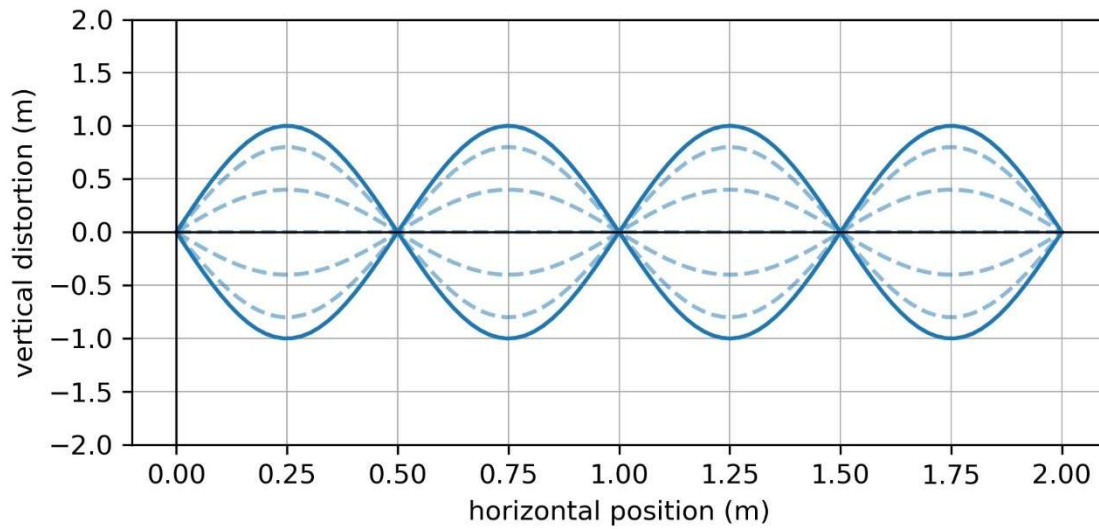


14. Two waves approach each other with speed  $v = 6$  m/s. At what time and where will these waves fully overlap and what will the wave look like at that time?



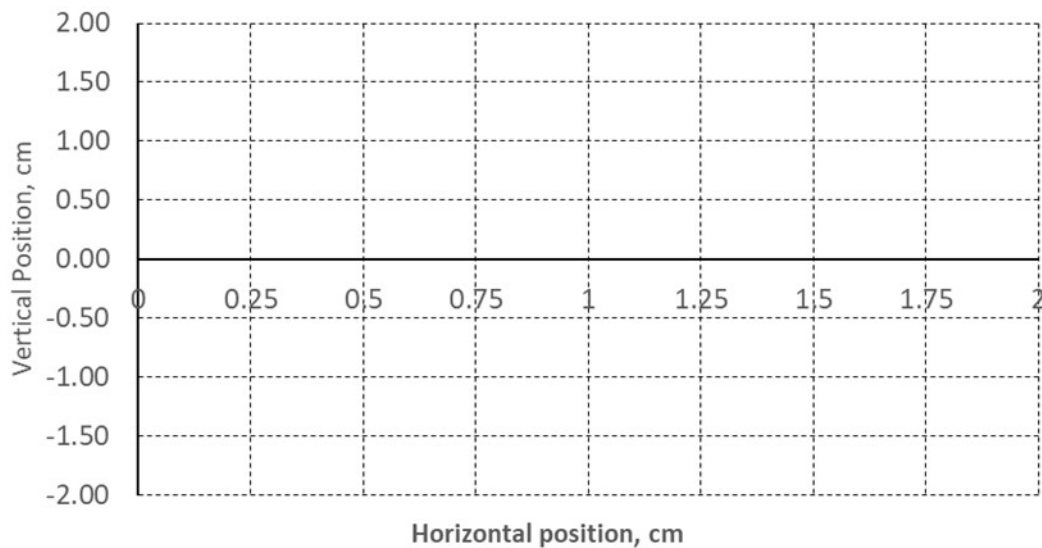


15. The plot below represents a standing wave in a string.



- a) How many antinodes are there?
- b) How many nodes are there?
- c) What is the wavelength of the standing wave?
- d) The speed of the wave on the string is  $v = 40$  m/s. Calculate the frequency and the period of oscillation of the standing wave?

16. Redraw the string from the above problem with three antinodes.



- a) What is the wavelength and frequency?
- b) Redraw it with 2 antinodes.
- c) What is the wavelength and frequency?
- d) Next, one antinode. What is the wavelength and frequency?
- e) What is the 10th harmonic frequency? What is the 10th harmonic wavelength?

17. Instead of changing the frequency to make fewer anti-nodes, we could change the velocity instead, and the easiest way to do that is to adjust the tension in the string. So, if the standing wave goes from 4 antinodes to 3 antinodes, by what ratio (factor) does the *speed* of the wave change? If the speed of the wave changes by this ratio, then by what ratio does the tension on the string need to change?
18. A wave has a 4<sup>th</sup> harmonic frequency of 200Hz. What is the fundamental frequency?
19. A standing wave is produced with a frequency of 98Hz; the next standing wave frequency is 112Hz. What is the fundamental frequency? How many antinodes were there for these two standing waves?

20. The tension in a string is increased by a factor of 1.3. By what factor is the fundamental frequency of a wave on the string changed?
21. The tension in a string is increased by 10%. By what percent is the fundamental frequency changed?