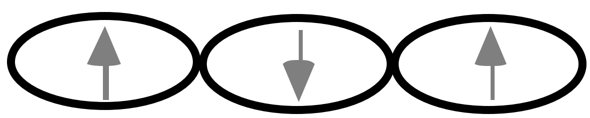
6: STANDING WAVES ON SPRINGS

Vibrating strings are important sound sources, particularly for musical instruments. Violins, guitars, pianos, and a whole host of instruments make sounds which begin with vibrating strings. The vocal cords are similar to vibrating strings. Furthermore, strings provide an exact visual analogy to air columns, which are used in many other instruments and which allow humans to control the timbre of the sounds that they make in speech.

The best way to "get a feel" for **standing waves** is to make some yourself on a long rope or spring. The waves that do not appear to move – are called **standing waves**. Their wavelike pattern results from the **interference** of two or more waves, in the case of strings, from an interference (superposition) of the generated wave and its reflection from the ends. A standing wave has regions of minimum and maximum amplitude called **nodes** and **antinodes**.

1 Standing Waves on a Spring with Fixed Ends

With the spring at **15 ft**, oscillate your arm back and forth, sending regularly spaced pulses down the spring. Vary the frequency of oscillation until you set up a standing wave that looks like this:



Each hump is one half of a wavelength, so this spring now has ***one and a half wavelengths*** on it. Since the spring is **15 ft** long, the wavelength of the standing wave is **10 ft.** Wavelength is the *length* of two humps, and is symbolized by the lower case Greek letter *l* (lambda).

With 3 humps on the spring, measure the amount of time required to make **20** complete oscillations. This is twenty periods.

What is *one* period of oscillation of this standing wave?

What is the frequency of oscillation?

I. Create a standing wave with *one wavelength* on the spring (two humps). **What is** *l*? (It is *not* 2. If you think the wavelength is 2, ask for help.) Measure the amount of time required to make **20** complete oscillations. This is **$20T$. What is the period of oscillation of this standing wave?**

II. **Put** this and the previous data into the appropriate spaces in the table below. Then complete the table by setting up standing waves with two complete wavelengths and with one half of a wavelength, measuring **$20T$** for each one. Include units. Leave the last column empty.

Data from standing waves on a spring fixed at both ends

looks like	# humps	l	$20T$	T	f	
	1				$f_1 =$	
	2					
	3	10 ft				
	4					

I. The frequencies should form a harmonic series. To find out if they do, divide each frequency by the fundamental frequency f_1. Label the last column f/f_1 **and fill it in.**

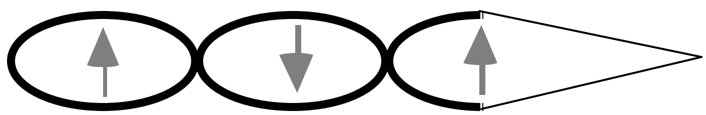
II. Are the other frequencies two, three, and four times the frequency of the fundamental?

Do not be discouraged if your results are not perfect. It is difficult to time the periods of the long spring accurately. Unfortunately, the fundamental is usually the least accurate of the measurements. If you find, for example, that the harmonics are 1.6, 2.5, and 3.4 times the fundamental, the problem is probably that the f_1 you calculated is too large. You might try assuming that the upper harmonics are correct and try to determine the expected fundamental.

2. Standing Waves on a Spring with a Free End (optional, extra credit)

Different kinds of standing waves can be created on a spring on which one end is free to move back and forth. To study these types of standing waves, have one person hold the end of the *string* which is attached to the end of the spring. The spring itself should still be stretched to 15 ft; the string just serves as a way to hold the spring without restricting its side-to-side movement. If the spring is stretched to the same length as before, then the speed of waves on the spring will also be the same as before.

Set up a standing wave that looks like this:



This is ***one and a quarter wavelengths.*** Each bulge in the spring is **(1/2)*l*,** so the part left over at the end, half a bulge, is (1/4)*l*. Since the spring is 15 ft long, the wavelength is (15 ft)/1.25 = 12 ft. You should be able to check this by counting the number of floor tiles that are taken up by the full wavelength.

I. Vary the frequency to generate different patterns. Notice that every pattern you make has a quarter of a wavelength (half of a hump) at the end held by the string. The lowest frequency pattern should have only half a hump (one-quarter wavelength).

b. **Measure** the period of the four lowest frequency standing waves you can make, filling in the table below in the same way as you did for the fixed-end spring. Remember that the string is not part of the standing wave pattern, and should not be shown in the picture you put in the "looks like" column.
It is more difficult to determine *l* for the free-end standing waves. The easiest way is to divide the length of the spring (15 ft) by the *number of wavelengths on the spring*. For this reason, an extra column for "number of wavelengths" has been added to the table.

Data from standing waves on a spring with a free end

looks like	**# humps**	# wavelengths	*l*	**20*T***	***T***	***f***	***f*/*f*₁**
						f_1 =	

	2 1/2	1 1/4	12 ft				

c. How does the fundamental frequency compare to the fundamental for the fixed-end spring? Why?

d. Do the frequencies form a harmonic series?