Name: ______________________

Class: ______________________

Due Date: ______________________

C.4 Standing Waves and Resonance

Understandings

- The nature and formation of standing waves in terms of superposition of two identical waves traveling in opposite directions.
- Nodes and antinodes, relative amplitude, and phase difference of points along a standing wave.
- Standing waves patterns in strings and pipes.
- The nature of resonance including natural frequency and amplitude of oscillation based on driving frequency.
- The effect of damping on the maximum amplitude and resonant frequency of oscillation.
- The effects of light, critical, and heavy damping on the system.

You need to watch animations on ***standing waves*** to perfectly understand it!:

https://www.acs.psu.edu/drussell/Demos/StandingWaves/StandingWaves.html

Topics C.1-C.3 dealt with **traveling waves**.
Topic C.4 deals with **standing waves**.
Please treat **standing waves** and **traveling waves** differently!

Something to think about: Imagine plucking a string from a musical instrument. What is happening in terms of physics and waves?

There are three popular examples of standing waves:

- Waves on a string (guitar) (closed closed)
- Sound waves in a pipe (flute) (open closed or open open)
- A vertical pipe with the top end open and the bottom end in water. The vertical pipe can be raised and lowered to change its length. A tuning fork is placed on top of the vertical pipe. (open closed)

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

1. C: List some observations which can be made from standing waves but not traveling waves.

2. C: Define the following terms:

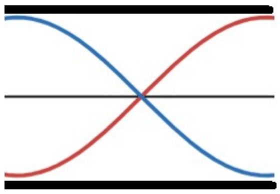
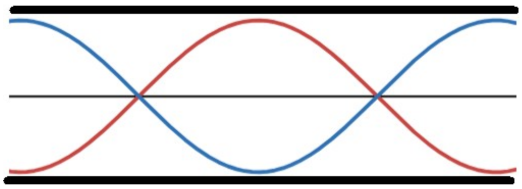
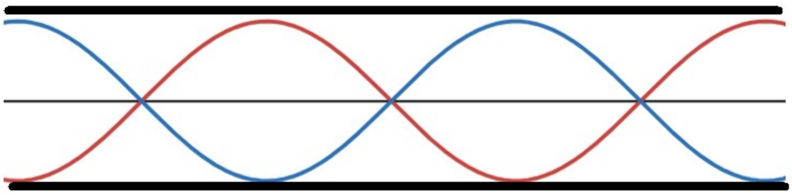
   a. Node:

   b. Anti-node:

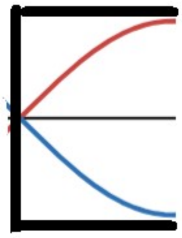
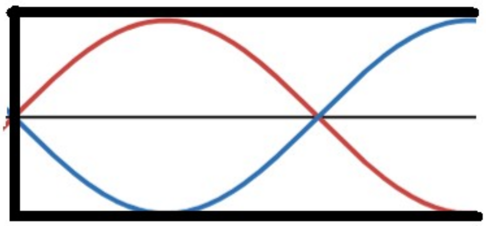
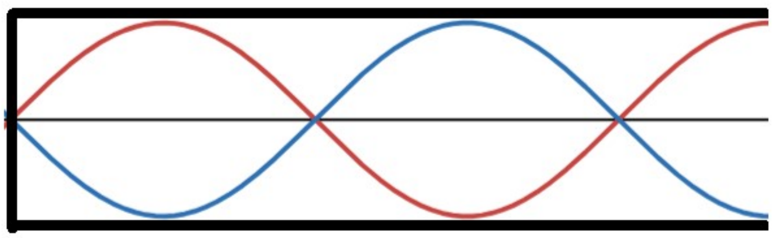
   c. First harmonic:

   d. Fundamental frequency:

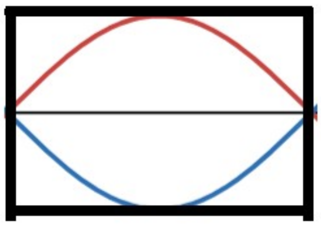
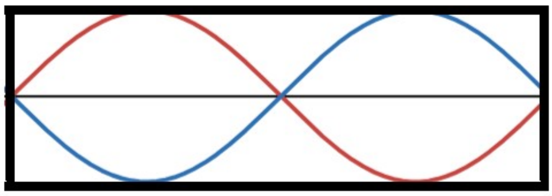
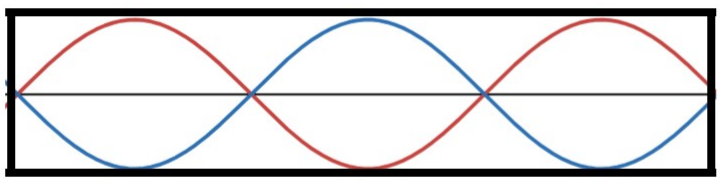
3. C: **Use a pencil and ruler!** Below are the first three harmonics of a tube with both ends open. The frequencies of the first three harmonics are derived for you. Draw and solve for the next three frequencies on the next page.

	$L = \frac{\lambda}{2}$ $\lambda = 2L$ $v = \lambda f$ $v = 2Lf$ $f = \frac{v}{2L}$
	$L = \lambda$ $\lambda = L$ $v = \lambda f$ $v = Lf$ $f = \frac{v}{L}$
	$L = \frac{3\lambda}{2}$ $\lambda = \frac{2L}{3}$ $v = \lambda f$ $v = \frac{2Lf}{3}$ $f = \frac{3v}{2L}$

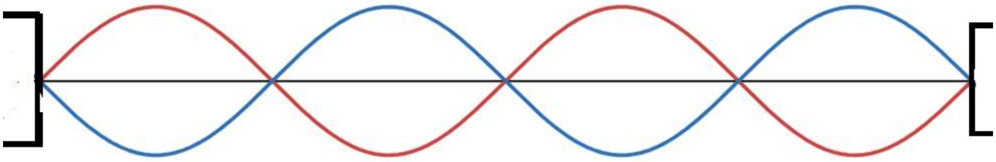
4. C: **Use a pencil and ruler!** Below are the first three harmonics of a tube with one end open and one end closed. The frequencies of the first three harmonics are derived for you. Draw and solve for the next three frequencies on the next page.

	$L = \frac{\lambda}{4}$ $\lambda = 4L$ $v = \lambda f$ $v = 4Lf$ $f = \frac{v}{4L}$
	$L = \frac{3\lambda}{4}$ $\lambda = \frac{4L}{3}$ $v = \lambda f$ $v = \frac{4Lf}{3}$ $f = \frac{3v}{4L}$
	$L = \frac{5\lambda}{4}$ $\lambda = \frac{4L}{5}$ $v = \lambda f$ $v = \frac{4Lf}{5}$ $f = \frac{5v}{4L}$

5. C: **Use a pencil and ruler!** Below are the first three harmonics of a tube with both ends closed. The frequencies of the first three harmonics are derived for you. Draw and solve for the next three frequencies on the next page.

	$L = \frac{\lambda}{2}$ $\lambda = 2L$ $v = \lambda f$ $v = 2Lf$ $f = \frac{v}{2L}$
	$L = \lambda$ $\lambda = L$ $v = \lambda f$ $v = Lf$ $f = \frac{v}{L}$
	$L = \frac{3\lambda}{2}$ $\lambda = \frac{2L}{3}$ $v = \lambda f$ $v = \frac{2Lf}{3}$ $f = \frac{3v}{2L}$

6. E: A string is stretched between two rigid supports which are 1.20 m apart. The string is plucked and it is noted that a standing wave is formed on the string which consists of five nodes, including the endpoints, and four antinodes.

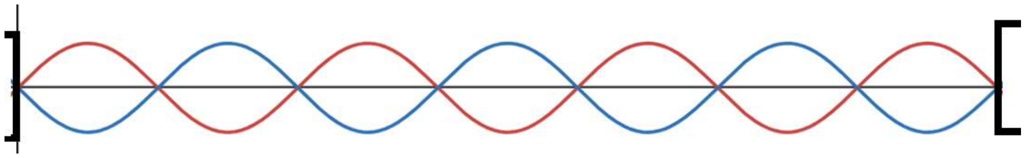


a. What is the wavelength of this standing wave?

b. If the frequency of this vibration is 220. Hz then what is the frequency of the fundamental frequency which will vibrate in this string?

c. What will be the frequency of the fifth harmonic which will vibrate in this string?

7. E: Transverse waves are being generated in a string between two fixed points which are 3.50 m apart by a wave oscillator which is generating a frequency of 28.0 Hz.



   a. What is the wavelength of the wave?

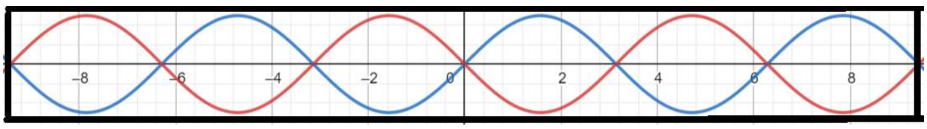
   b. What is the speed of the wave?

   c. What is the lowest frequency which could be used to generate a standing wave in this string?

   d. What is the wavelength of the lowest frequency wave which could form a standing wave in the string?

   e. What other frequencies could form standing waves in the string?

8. E: Consider the string vibrating below and forming a standing wave with a frequency of 180. Hz. The length of this string is 1.50 m.



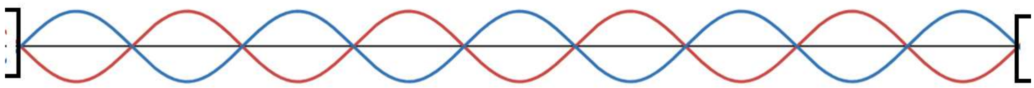
a. What is the wavelength of the wave?

b. What is the speed of the wave?

c. What is the fundamental frequency which will resonate in the string?

d. What will be the frequency of the third harmonic which will resonate in the string?

e. What will be the frequency of the ninth harmonic which will resonate in the string?

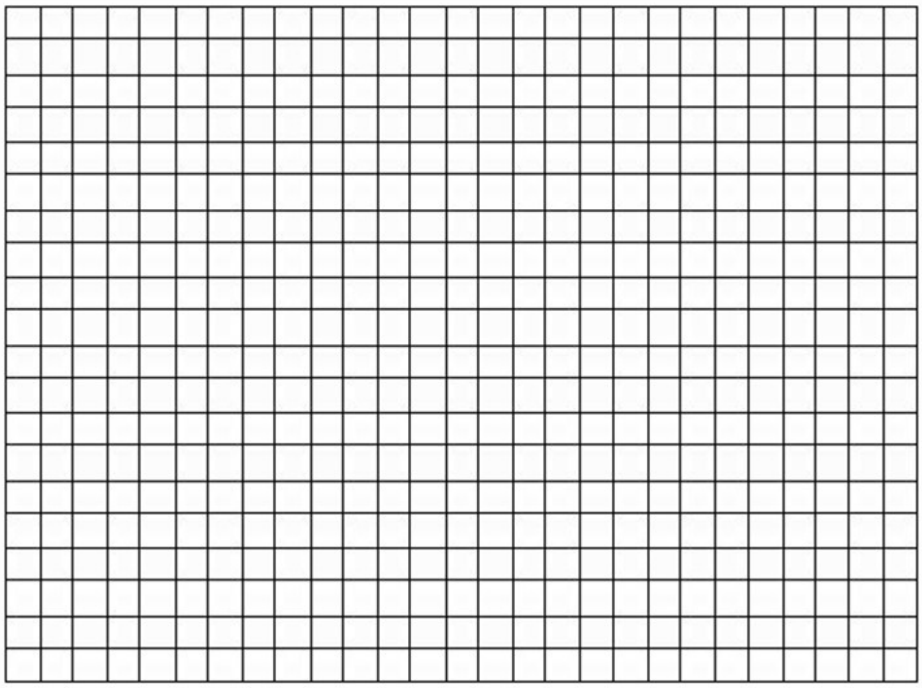


9. C: What is a *restoring force*?

10. C: What are some characteristics for *simple harmonic motion?*

11. C: Define *free oscillation.*

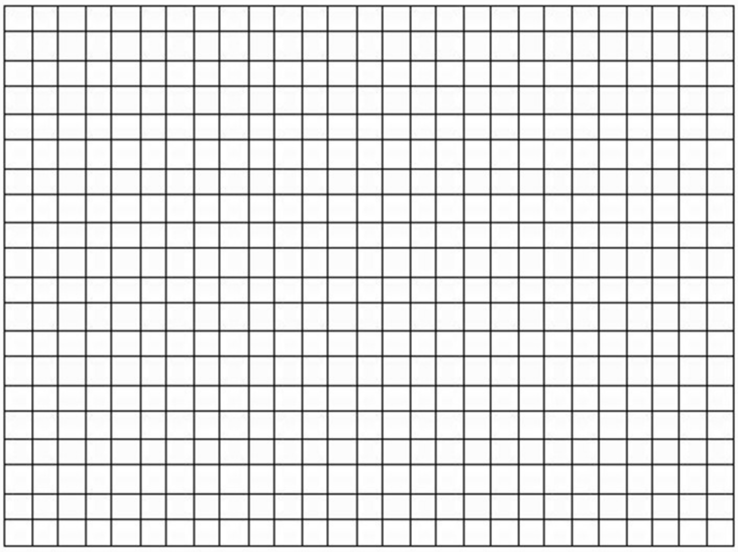
12. C: **Use a pencil!** Label and draw a *displacement vs. time* graph for a *free oscillation.*



13.C: Define *damping*.

14.C: Define *underdamping* (or *light damping*).

15.C: **Use a pencil!** Label and draw a *displacement vs. time* graph for an *underdamped system.*



16.C: Define *overdamped motion*.

17.C: **Use a pencil!** Label and draw a *displacement vs. time* graph for *overdamped* motion.

18.C: Define *critically damped motion*.

19.C: **Use a pencil!** Label and draw a *displacement vs. time* graph for a *critically damped system.*

20.C: What is a *driving force?*

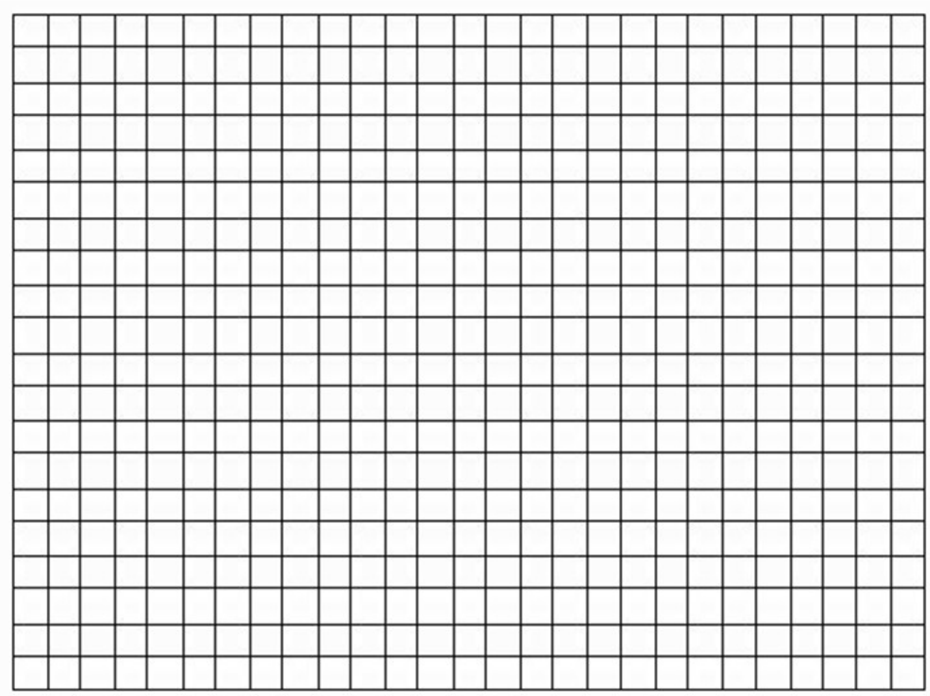
21.C: Define *natural frequency.*

22.C: Define *resonance*. When does *resonance* occur?

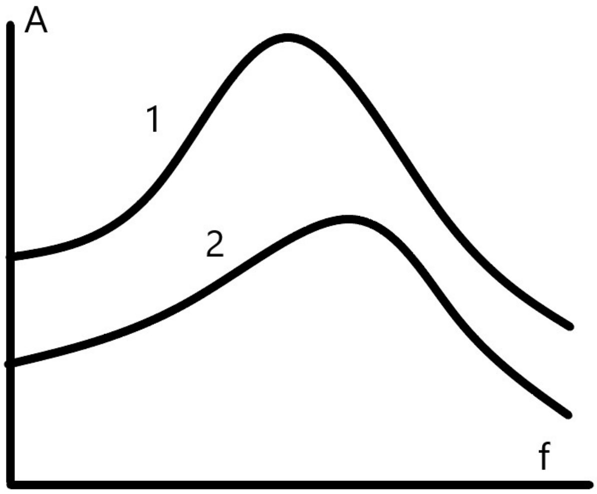
23.C: What happens to the amplitude of an object when the *natural frequency* of the object is much lower or much higher than the *driving frequency*?

24.C: What happens to the amplitude of an object when the *natural frequency* of the object is approximately equal to the *driving frequency*?

25.C: Draw an *amplitude vs. frequency* graph of an object oscillating with a driving force and a damping force.



26.E: Two oscillators are experiencing forced oscillations at a frequency near to the natural frequency of each oscillator. The graph below shows the amplitude with forcing frequency for each oscillator:



a. Which system, 1 or 2, has a greater amount of damping?

b. Which system, 1 or 2, has a greater natural frequency of oscillation?

27.C: List some effects of resonance in the real world.