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!

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

2. Define the following terms:

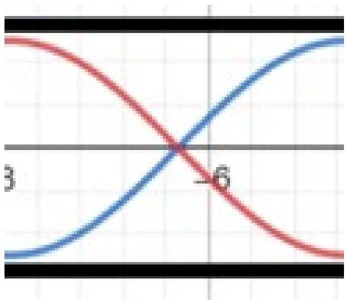
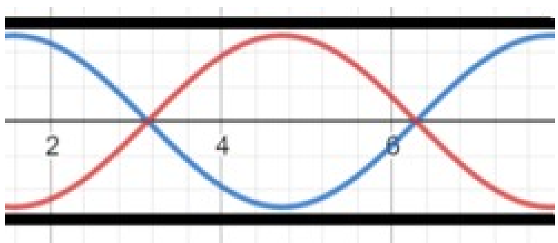
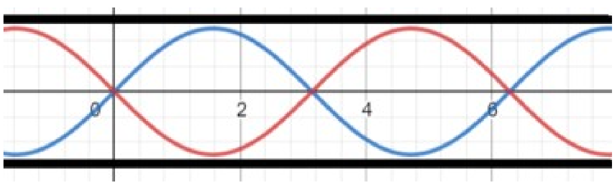
    a. Node:

    b. Anti-node:

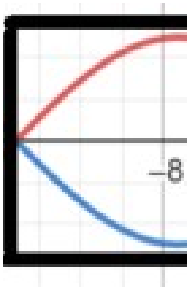
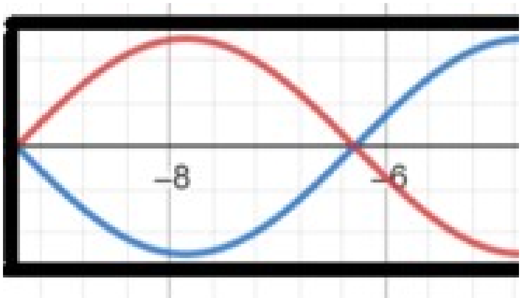
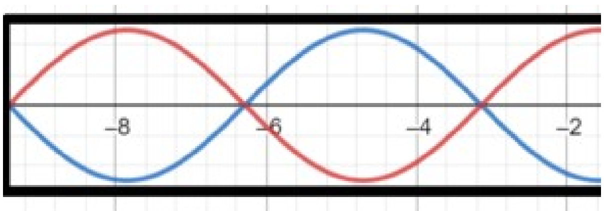
    c. First harmonic:

    d. Fundamental frequency:

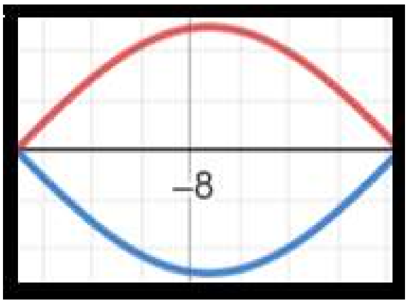
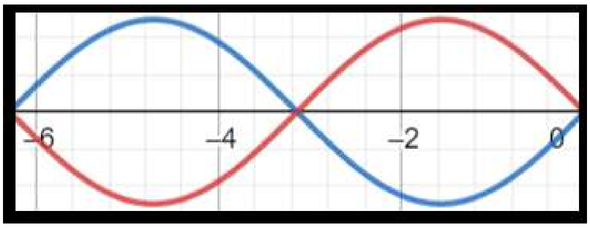
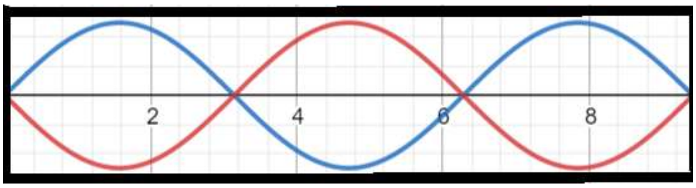
3. **Use a pencil and ruler!** Below are the first three harmonics of a tube with both ends open. The frequencies of the first three harmonics are derived for you. Draw and solve for the next three frequencies on the next page.

 Image from https://www.geogebra.org/	$L = \frac{\lambda}{2}$ $\lambda = 2L$ $v = \lambda f$ $v = 2Lf$ $f = \frac{v}{2L}$
	$L = \lambda$ $\lambda = L$ $v = \lambda f$ $v = Lf$ $f = \frac{v}{L}$
	$L = \frac{3\lambda}{2}$ $\lambda = \frac{2L}{3}$ $v = \lambda f$ $v = \frac{2Lf}{3}$ $f = \frac{3v}{2L}$

4. **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.

 Image from https://www.geogebra.org/	$L = \frac{\lambda}{4}$ $\lambda = 4L$ $v = \lambda f$ $v = 4Lf$ $f = \frac{v}{4L}$
	$L = \frac{3\lambda}{4}$ $\lambda = \frac{4L}{3}$ $v = \lambda f$ $v = \frac{4Lf}{3}$ $f = \frac{3v}{4L}$
	$L = \frac{5\lambda}{4}$ $\lambda = \frac{4L}{5}$ $v = \lambda f$ $v = \frac{4Lf}{5}$ $f = \frac{5v}{4L}$

5. **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.

 Image from https://www.geogebra.org/	$L = \frac{\lambda}{2}$ $\lambda = 2L$ $v = \lambda f$ $v = 2Lf$ $f = \frac{v}{2L}$
	$L = \lambda$ $\lambda = L$ $v = \lambda f$ $v = Lf$ $f = \frac{v}{L}$
	$L = \frac{3\lambda}{2}$ $\lambda = \frac{2L}{3}$ $v = \lambda f$ $v = \frac{2Lf}{3}$ $f = \frac{3v}{2L}$

6. What is a *restoring force*?

7. What are some characteristics for *simple harmonic motion?*

8. Define *free oscillation.*

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

10. Define *damping.*

11. Define *underdamping* (or *light damping*).

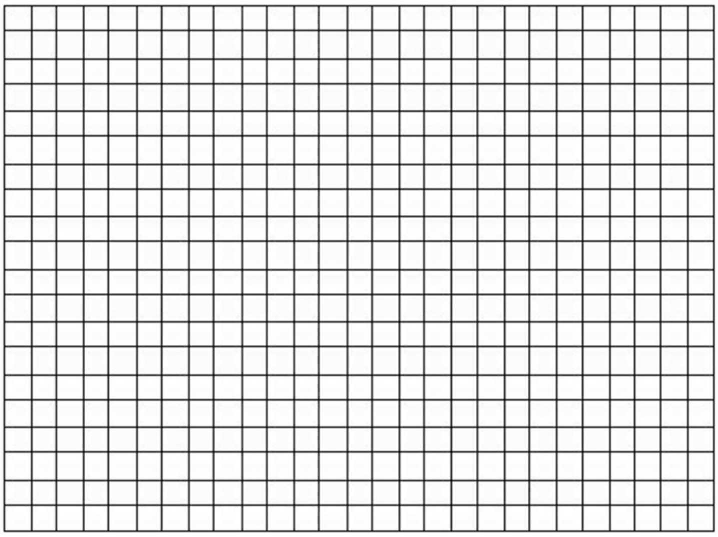
12. **Use a pencil!** Label and draw a graph for an *underdamped system.*

13. Define *overdamped motion*.

14. **Use a pencil!** Label and draw a graph for *overdamped* motion.

15. Define *critically damped motion*.

16. **Use a pencil!** Label and draw a graph for a *critically damped system.*



17. What is a *driving force?*

18. Define *natural frequency.*

19. 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*?

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

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

22. Define *resonance.*

23. List some effects of resonance in the real world.