

HTML5 lab app relating circular motion to harmonic motion and the wave relation

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Abstract

A free HTML5 application by the authors is available for students to use in a laboratory investigation of circular motion, harmonic motion, and the wave relation. The advantage of an HTML5 app is that it can run in a browser such as Google Chrome with no additional plug-ins. The app can be accessed from the Internet or from the hard drive of the student's computer. Activities include measuring wavelengths and periods of sine waves, as well as determining wave speed from a spreadsheet plot of period versus wavelength. Students find the visualization of the generated sine wave aesthetically appealing.

Introduction

The classic relationship between simple harmonic motion and a circle can be traced back to Newton [1]. Recently the connection between circular motion and sine waves has been effectively illustrated through videos [2-3] and interactive computer apps [4-6]. These resources are most welcome as computers and video clips have become more common in physics classes and labs. A recent example of a computer laboratory in *Physics Education* is the 'virtual physics laboratory, "PhysLab", created using 3D video game technology suitable for advanced level physics courses in secondary schools' [7]. Another recent paper employs EduPython to develop interactive simulations in secondary education [8].

The circleSine app

Our circleSine app, developed along the lines of the videos and apps mentioned above, includes added features so that teachers can employ the app in a laboratory setting where students make measurements. The app is written in HTML5, JavaScript, and Cascading Style Sheets (CSS), requiring only a browser to run. The program can be accessed through the Internet or from the hard drive of a computer. It can also run on mobile devices through Internet browsers.

Teachers are free to use our app directly from our website [9]. They can also download the software and distribute it to their students or even upload the program to their school websites. The license is Creative Commons (CC) for non-commercial use with attribution, share alike.¹ Figure 1 is a screenshot of the app. The included draggable ruler has been moved into position to measure the wavelength in figure 1. The distance units are centimetres and the wave displayed in figure 1 has a wavelength equal to 30 cm. The actual length of the wave on the display screen will depend on the resolution of the device used by the student. The user can control the amplitude and wavelength with sliders or the preset buttons. The Pause/Start button freezes the wave or allows the wave to continue. The Centre button centres the blue bead inside the circle.

The red bead at the moment of the screenshot in figure 1 is on the horizontal axis at 10 cm. This bead moves along the red circumference counterclockwise. The blue bead is the vertical projection of the red bead's height and oscillates as a sine wave. As the blue bead moves up and down, a sine wave is traced out to the right similar to how an oscilloscope displays a wave. The student visualizes one of the most important connections in mathematics – the relationship between the sine wave of simple harmonic motion and the circle. The ensuing understanding gives the student insight into the sine function which is first introduced in trigonometry with the unit circle, a circle

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similar to the large red circle in figure 1.

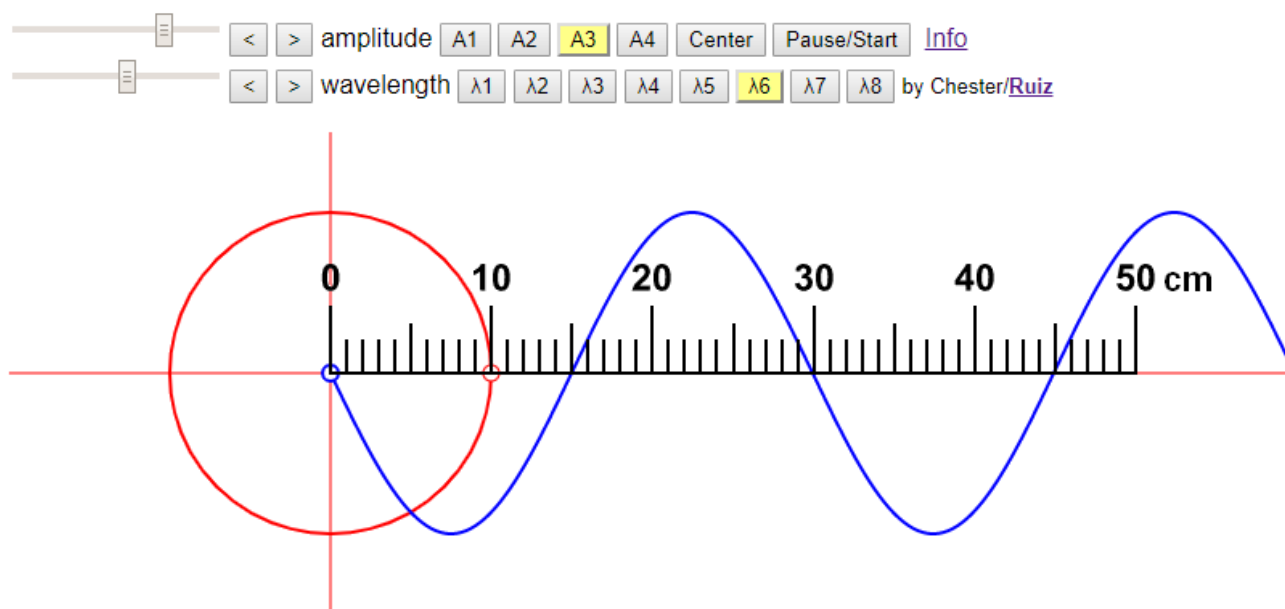


Figure 1. Screenshot of app with draggable ruler in position to measure the wavelength.

Suggested uses of the circleSine app

Students can be asked if changing the amplitude, frequency, wavelength, or period affects the wave speed. One student can follow a crest moving to the right with a finger or pen as another student presses buttons to change the amplitude or wavelength. The wave speed will not change. Some students may be surprised that the wave speed remains the same. The teacher can ask students if they hear louder sounds from a band before they hear the softer sounds. What about higher pitches versus the bass? They will readily conclude from experience that wave speed is independent of the parameters controlled by the sources of the sound waves.

The wavelength can be measured by moving the draggable ruler to the position shown in figure 1. First the wave should be paused and then the Centre button clicked so that the blue bead is centred vertically. The period can be measured by starting the wave with the Pause/Start button and using a smartphone stop watch. When the blue bead reaches the highest height, the timer is started

with the count of zero. Then the timer can be stopped when the count reaches ten. The period is found by dividing the total time in seconds on the timer by ten. The reciprocal of the period (s) is frequency in cycles per second or hertz (Hz). The wave speed will always be equal to the wavelength times the frequency. The wave speed can also be estimated directly by timing how long it takes for a crest to travel 50 cm per the ruler.

Playing with the app will lead students to understand that longer wavelengths are correlated with lower frequencies and shorter wavelengths with higher frequencies. They can use the app to answer the question as to what happens to the frequency if the wavelength doubles. Students can also plot period measurements and wavelengths with a spreadsheet. The wave speed is given by the reciprocal of the slope when period is plotted against wavelength. This more precise method of determining the wave speed can be compared with the other methods discussed above.

Conclusion

The circleSine app shows how circular motion is related to a traveling sine wave. Students can explore amplitude, wavelength, period, frequency, and wave speed. The app can be run from the link given in Ref. 9. The source code can also be downloaded in order to run the app from a computer hard drive where connection to the Internet is not required. As long as the computer has a browser such as Google Chrome, the program will run. Teachers can also upload the app to a web server if they would like. The source code consists of three files: circleSine.html, circleSineRuler.gif, and info.html. The three files need to be placed in the same directory. The animation of the app will be appealing to students and generate interest for learning the physics.

Acknowledgments

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app. We would also like to thank [w3schools.com](http://www.w3schools.com) for explaining how to code draggable objects.

References

- [1] Roche J 2002 Introducing simple harmonic motion *Phys. Educ.* **37** 497-506
- [2] Meritnation 2011 Understanding uniform circular motion and how it works (YouTube) <https://www.youtube.com/watch?v=cx-qHZwslqs>
- [3] Khan Academy 2016 Sine and cosine from rotating vector (YouTube) https://www.youtube.com/watch?v=a_zReGTxdIQ
- [4] Open Educational Resources / Open Source Physics @ Singapore 2019 (Singapore: Open Source Physics) <https://iwant2study.org/ospsg/index.php/interactive-resources/physics/04-waves>
See the app: Transverse phase difference wave JavaScript HTML5 Applet Simulation Model
- [5] PhET Interactive Simulations 2019 (Boulder, Colorado, USA: University of Colorado Boulder) https://phet.colorado.edu/sims/html/wave-on-a-string/latest/wave-on-a-string_en.html
- [6] Explore math with Desmos 2019 (San Francisco, California, USA: Desmos, Inc.) <https://www.desmos.com/calculator/kxfekf0kgb>
- [7] Price C B and Price-Mohr R 2019 PhysLab: a 3D virtual physics laboratory of simulated experiments for advanced physics learning *Phys. Educ.* **54** 035006
- [8] Binek S, Kimla D, Jarosz J, and Styc K 2018 Using computer simulation to aid the interactive learning of physics in secondary education *Phys. Educ.* **53** 055006
- [9] Ruiz M J 2019 Software: circleSine (<http://www.mjtruiz.com/ped/circleSine/>)

Authors



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