Attenuation of a circular wave

FizziQ activity · High school · 25 min

Scan to open in FizziQ

Virtual floats at growing distances record a circular wave's amplitude in the online FizziQ Web lake simulation; an amplitude-distance plot reveals the $1/\sqrt{r}$ decay.

Learning objectives

- Observe and measure wave amplitude attenuation with distance
- Record the vertical motion of floats at different distances
- Plot and interpret an amplitude versus distance graph
- Verify the $1/\sqrt{r}$ law for circular 2D waves
- Understand that attenuation results from energy spreading, not energy loss

Instruments and sensors

FizziQ Web Waves on a Lake simulation

Materials

- Computer, tablet, or smartphone with FizziQ Web installed
- Note: the protocol remains adaptable to any comparable simulation or virtual wave-lab tool.

Protocol

1. Open the Waves on a Lake simulation in FizziQ Web. Set the frequency to 1.0 Hz, the speed to 2 m/s, and the amplitude to 1.0 m.
2. Place a first float close to the source (for example at 1 m from the center). Start the simulation and record (REC) the vertical motion of the float for a few oscillations.
3. Stop the recording. In the experiment notebook, measure the float's amplitude (maximum oscillation height).
4. Move the float to a greater distance (2 m) and repeat the recording. Measure the new amplitude.
5. Continue with increasing distances: 3 m, 4 m, 5 m, 6 m. Note the amplitude for each distance in a table.
6. Create a table with two columns: Distance r (m) and Amplitude A (m). Plot the graph of A versus r.
7. Is the curve a straight line? If not, try plotting A versus $1/\sqrt{r}$. Do you obtain a straight line?
8. Also observe the oscillation period of the different floats. Does the period change with distance?
9. Launch a simulation with a larger amplitude (2.0 m). Is the relative attenuation the same?
10. Conclusion: the amplitude decreases with distance, but the frequency and speed remain unchanged. The wave weakens but does not slow down.

Expected results

The amplitude decreases as distance increases. For a circular 2D wave, the amplitude theoretically follows $A = A_0/\sqrt{r}$. The period and frequency of the float oscillations remain identical regardless of distance. The graph A(r) is a decreasing curve (not a straight line), but $A(1/\sqrt{r})$ is linear, confirming the $1/\sqrt{r}$ law. Doubling the source amplitude doubles all measured amplitudes but the relative attenuation pattern remains the same.

Questions

- Why does the amplitude decrease with distance even though total energy is conserved?
- How does the $1/\sqrt{r}$ decay (2D) differ from the $1/r$ decay (3D)?

- Does the frequency of a float change with its distance from the source?
- If you double the source amplitude, does the amplitude at 5 m also double?
- Why is geometric attenuation not an energy loss but an energy redistribution?
- In what situation would a wave not attenuate at all?

Going further

- Vary the frequency and verify that the relative attenuation does not depend on frequency in this model
- Compare the motion of two floats at different distances to measure the time delay between them
- Use the measured time delay to calculate the wave propagation speed
- Investigate how the amplitude-distance relationship changes if the simulation could model 3D spherical waves
- Record amplitude data at many distances and perform a least-squares fit to verify the exponent in A ∝ r^n