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MCNAIR SCHOLARS PROGRAM

Acoustic Levitation and Quantum-Like Behavior of Styrofoam Balls

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ABSTRACT

We are investigating acoustic waves (28,000 Hz) as they guide Styrofoam balls in combination with schlieren imaging. The first arrangement is a standing acoustic wave that levitates the Styrofoam balls. We used the acoustic radiation force to predict the spatial pattern of the balls. The second arrangement is a double-slit acoustic system with Styrofoam balls launched evenly into the slits. The purpose is to see if the acoustic double-slit system can be a systematic visual analogue to a double-slit electron diffraction system using De Broglie-Bohm's Theory. The role of the electron is played by a Styrofoam ball and the role of the guiding wave is played by the acoustic wave.

SCHLIEREN IMAGING

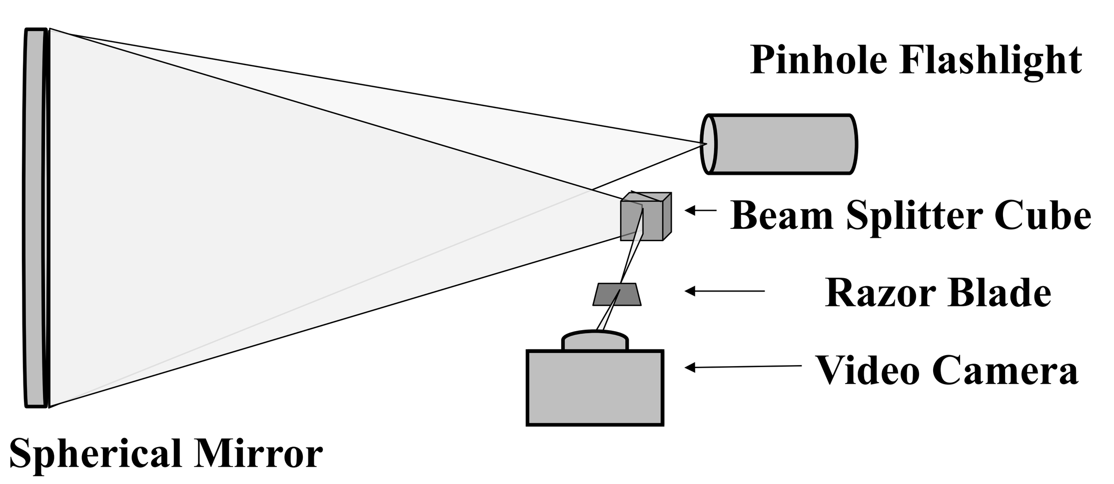


Figure 1: Schlieren imaging system setup, which is used to see the varying pressure of air (air flow).

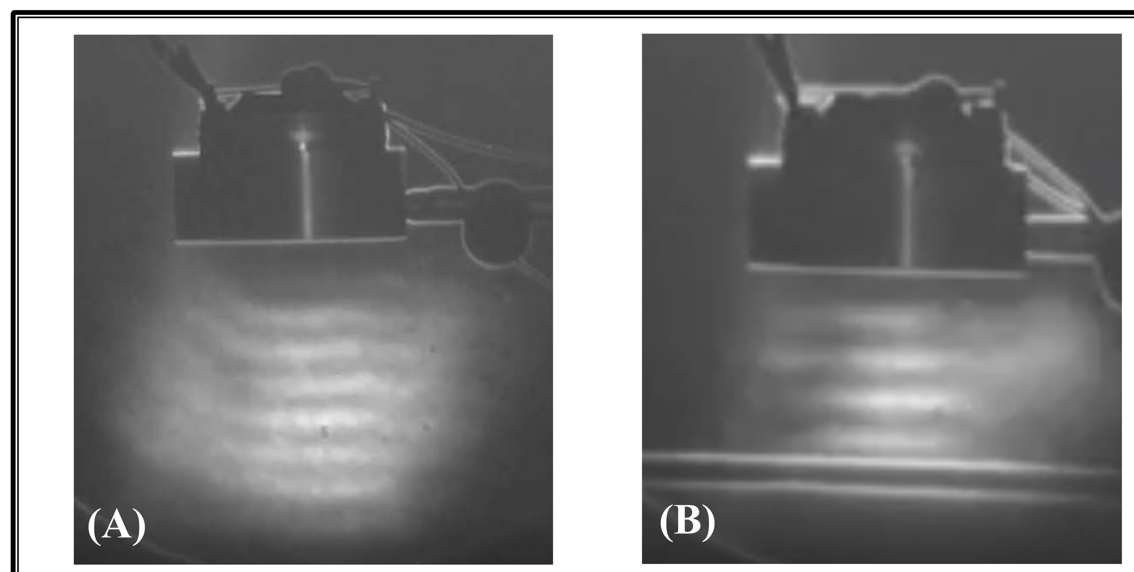


Figure 2: Using schlieren imaging we can see sound waves, which are varying pressure waves. This is done by having the flashlight strobe at the same frequency of the sound wave, allowing the camera to always see the same spatial pattern. (A) traveling sound wave; (B) standing sound wave.

Reference: *Harvard Natural Sciences Lecture Demonstrations Schlieren Optics.*

SCAN FOR videos of schlieren imaging!

ACOUSTIC RADIATION FORCE

Acoustic Pressure Function

$$P_{in}(x,t) = P_o \cos(kx)\sin(\omega t)$$

Acoustic Potential Energy

$$U = V_o\left(\frac{P_o^2}{4\rho_f c_f^2}\right)\left[\cos^2(kx)\left(1-\frac{\rho_f c_f^2}{\rho_p c_p^2}\right)-\frac{3}{2}\sin^2(kx)\left(\frac{2(\rho_p-\rho_f)}{2\rho_p+\rho_f}\right)\right]$$

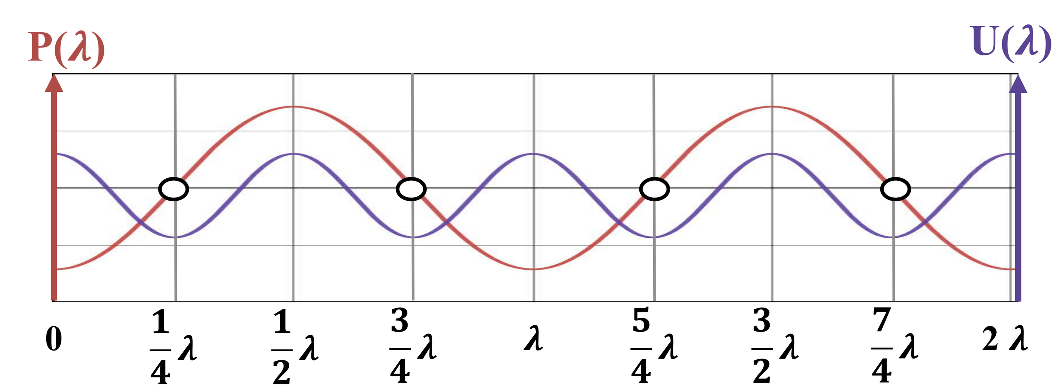


Figure 3: Based on the acoustic potential energy, we can predict that the Styrofoam balls tend to move toward the nodes (o) of the pressure wave.

ACOUSTIC LEVITATION

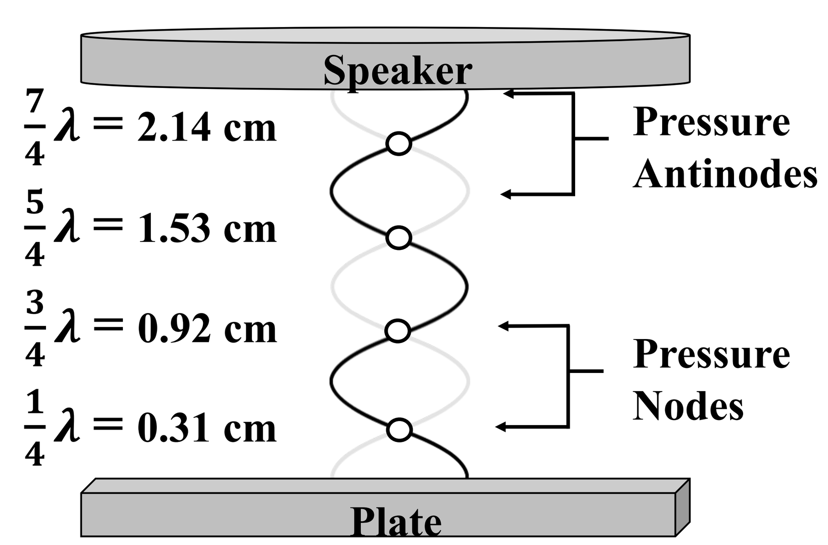
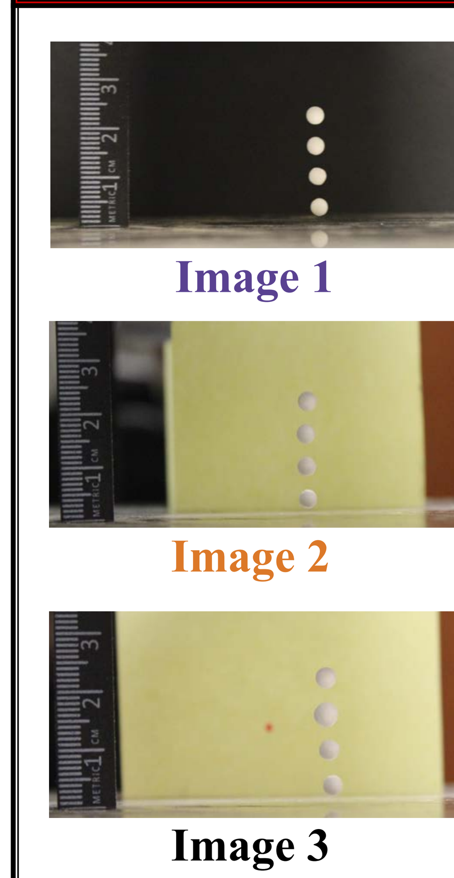


Figure 4: A geometric representation shows the expected vertical positions relative to the plate.

Reference: *Acoustic Levitation and the Acoustic Radiation Force* (David P. Jackson, Ming-Hua Chang).

LEVITATING BALLS



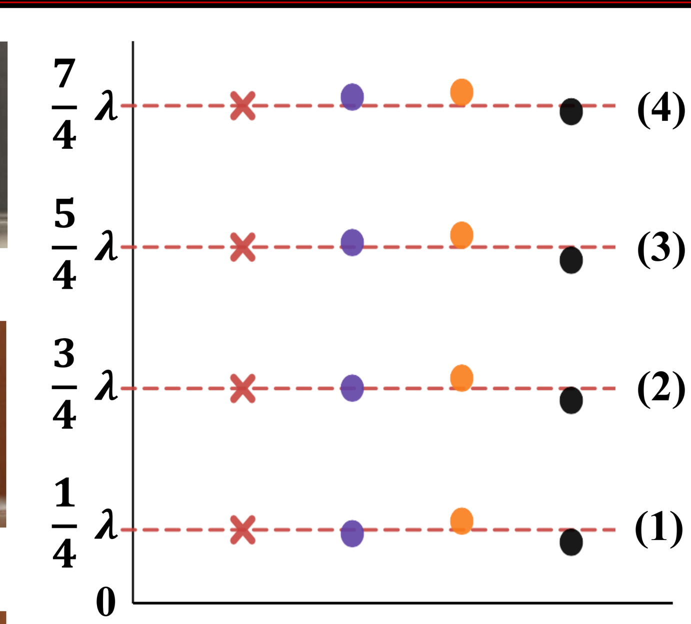


Figure 5: Data collected from 3 images (O) compared to predicted values from the acoustic radiation force (X).

LEVITATION ANALYSIS

Position of Balls Percent Error

Ball	Image 1	Image 2	Image 3
(4)	1.87 %	2.73 %	1.42 %
(3)	1.29 %	3.16 %	4.08 %
(2)	0.00 %	4.17 %	5.75 %
(1)	6.90 %	11.43 %	19.2 %

Based on these results, the acoustic radiation force can be used to map the positions of the Styrofoam balls as they levitate in the acoustic standing wave. It must be noted, that the dB reading calculated [144 dB] based on the required force to levitate the balls was much too high for our constructed system [132 dB max].

DOUBLE-SLIT DIFFRACTION

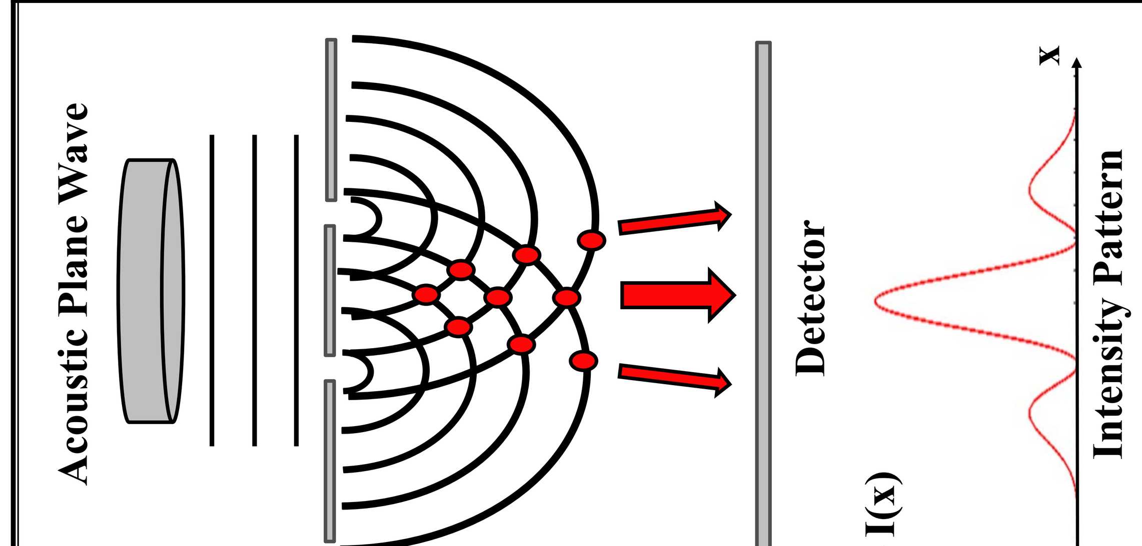


Figure 6: Shows an incident acoustic plane wave diffracting as it passes through a double-slit. Interference of the acoustic waves causes an intensity pattern that is shown on the right side.

PRELIMINARY FINDINGS

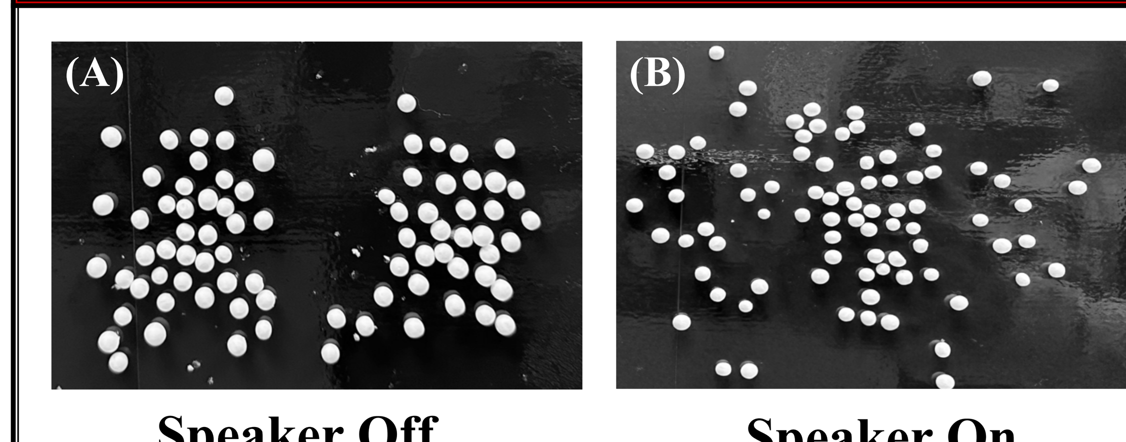


Figure 7: The Styrofoam balls were launched into the acoustic diffraction system one at a time with the speaker off (A) and speaker on (B). Based on the resulting patterns, we hypothesize that it is possible for the acoustic system to be a visual analogue to double-slit electron diffraction.

VISUAL ANALOGUE

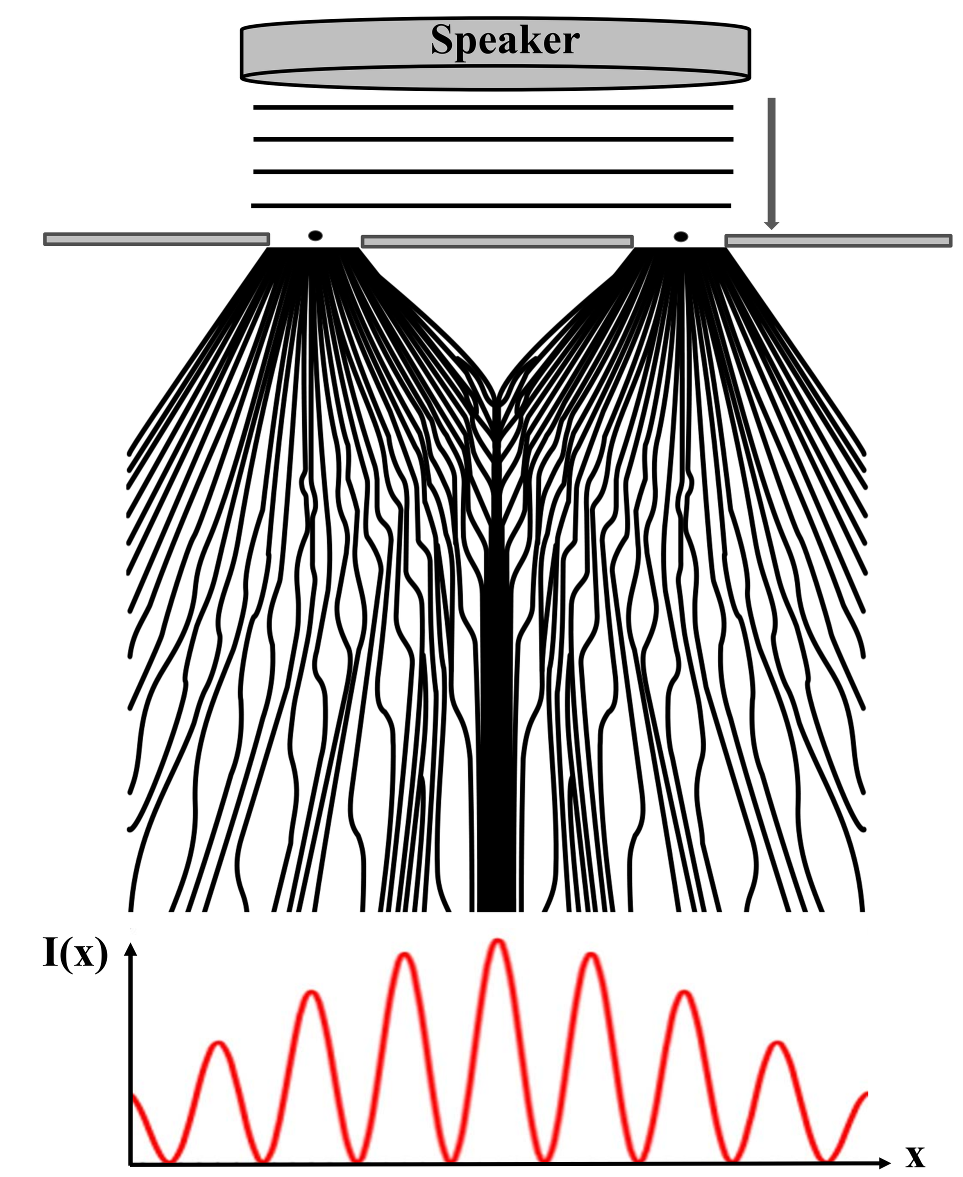


Figure 8: Bohmian trajectories mapped onto an acoustic double-slit system with Styrofoam balls. Below is the corresponding intensity pattern that is formed by the particles following the trajectories.

CONCLUSIONS

We found that the acoustic radiation force can be used to map the positions of the Styrofoam particles as they levitate in the acoustic standing wave system with minimal error. Although we must further investigate the discrepancy in the decibel reading to ensure that there are no other factors involved in the model.

Future Work: Create a simulation that shows the Bohmian trajectories of a double-slit electron diffraction system and compare this to the experimental trajectories of the Styrofoam balls in the acoustic system. If these two systems were to match, the visual analogue system could be used as an educational tool to teach about quantum mechanics using the De Broglie-Bohm theory.

SCAN FOR helpful references & more fun videos!