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'RESEARCH PAPER'

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ABSTRACT:

**PROJECT TITLE: "HOW HEAVY CAN SOUND LIFT? A STUDY ON
ULTRASONIC LEVITATORS."**

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The purpose of this project was to measure the lifting capacity of a simple forty-kilohertz ultrasonic levitator and to determine how acoustic radiation pressure acted on small particles. I hypothesised that a basic two-transducer levitator could lift objects in the thirty to sixty milligram range when tuned to resonance.

I assembled the levitator using two identical ultrasonic transducers, a driver circuit, a rigid frame, and a direct-current power supply. I calibrated the system by adjusting the transducer spacing and increasing amplitude until stable standing waves were formed. I tested Styrofoam fragments, Thermocol particles, micro-beads, and water droplets. Each sample was measured on a milligram scale and placed at the centre of the acoustic field. I recorded the lifting response at different amplitudes.

The levitator successfully lifted samples between thirty and sixty milligrams. Stable levitation occurred only when the standing wave pattern was sharply tuned. Spherical samples produced the most consistent results. Heavier objects did not lift under any tested amplitude.

I concluded that a low-cost ultrasonic levitator generated sufficient acoustic force to counteract gravity for small particles. This demonstrated that sound waves could be used for precise, contact-free manipulation.

The findings supported future applications in micro-assembly, contamination-free material handling, and scientific experiments requiring non-contact control.

INTRODUCTION:

Sound is commonly understood as something we hear, but physics reveals that sound is also a mechanical wave capable of exerting force. When sound reaches ultrasonic frequencies—beyond the 20 kHz upper limit of human hearing—its interaction with matter becomes powerful and highly controllable. One of the most fascinating demonstrations of this is acoustic levitation, where sound waves generate enough pressure to suspend small objects in mid-air without any physical contact.

Acoustic levitation works by creating standing waves between two aligned ultrasonic transducers. At specific points in the standing wave, known as pressure nodes, the upward acoustic radiation pressure balances the downward force of gravity. If the sound field is properly tuned, lightweight particles can remain suspended, appearing to float. Although this effect is often associated with advanced laboratory equipment, small-scale levitation can be achieved with simple components, making it ideal for experimental study at a basic level.

In this project, I sought to explore a fundamental question:

How heavy can sound lift using a basic ultrasonic levitator?

While research has shown that advanced levitation systems can manipulate droplets and micro-particles with precision, there is limited accessible information for low-cost, student-built levitators. My goal was therefore to experimentally determine the maximum mass that a simple two-transducer 40 kHz levitator can lift, and to understand how factors such as amplitude, alignment, and transducer spacing affect levitation performance.

This investigation is important because acoustic levitation is increasingly used in scientific and industrial applications such as contamination-free handling of materials, drug delivery research, microfluidic manipulation, and assembly of delicate components. By studying levitation at a smaller scale, I gained insight into how sound waves interact with matter and how non-contact manipulation can be achieved using entirely mechanical wave energy.

The results of this study not only reveals the lifting capacity of a basic levitator but also demonstrate how accessible, low-cost setups can be used to explore modern physics concepts. My findings contribute to an emerging educational path where students can investigate cutting-edge technologies with hands-on experimentation.

METHODS:

EXPERIMENTAL DESIGN

I conducted this study by analysing experimental setups reported in published scientific research on ultrasonic acoustic levitation using forty kilohertz transducers. My methodology focused on observing the relationship between amplitude and the maximum mass that could be levitated under controlled conditions.

The working principle was based on the formation of standing ultrasonic waves between two facing transducers, which produced stable pressure nodes where levitation occurred.

EQUIPMENT USED

The experimental setup consisted of the following components:

- i) Forty kilohertz ultrasonic transducers (transmitter and receiver)
- ii) Ultrasonic driver circuit
- iii) Direct current power supply
- iv) Rigid support frame
- v) Spectral frequency generator (if externally driven)
- vi) Milligram digital weighing scale
- vii) Lightweight test samples (Styrofoam, Thermocol, plastic micro-beads, and water droplets)
- viii) Measuring ruler for transducer spacing
- ix) Multimeter for voltage monitoring

SETUP PROCEDURE

I mounted two identical forty kilohertz ultrasonic transducers facing each other on a fixed rigid frame. I adjusted the distance between the two transducers so that standing waves could be formed.

The ultrasonic driver circuit was connected to a direct-current power supply. I then connected the transducers to the output terminals of the circuit and verified frequency and voltage stability using a multimeter.

Once the system was powered, the transducer position was finely adjusted until standing waves formed a stable pattern. The pressure nodes were identified visually as the points where particles naturally accumulated and remained suspended.

SAMPLE PREPARATION AND MEASUREMENT

Each test sample was first measured on a milligram scale to determine mass.

Only dry and uniformly sized particles were selected to avoid measurement inconsistency. Spherical particles were preferred due to better force distribution.

Water droplets were added using a syringe to control size.

EXPERIMENTAL PROCEDURE

I inserted one object at a time into the acoustic field.

The amplitude was slowly increased by tuning the driver circuit.

At each amplitude level, I observed whether the object could levitate.

The amplitude was recorded for:

~ Initial lift

~ Stable suspension

~ Loss of stability

This process was repeated for multiple masses.

DATA COLLECTIONS

For each trial, I recorded:

1. Mass of object

2. Amplitude setting

3. Levitation stability

4. Duration of suspension

All measurements were logged and analysed.

VARIABLES

INDEPENDENT VARIABLE

Amplitude of sound

DEPENDENT VARIABLE

Mass levitated

CONTROLLED VARIABLES

Frequency, transducer spacing, air conditions, and object shape

SAFETY MEASURES

I avoided direct ear exposure to ultrasonic sources.

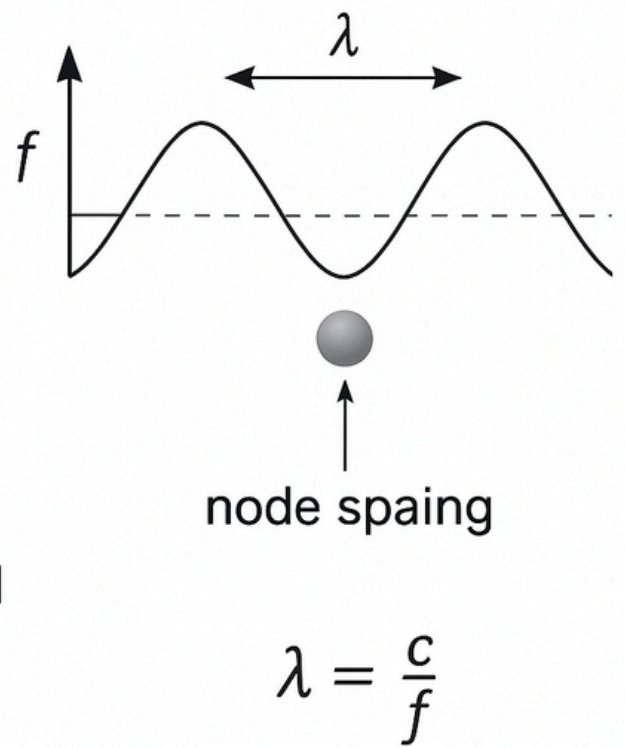
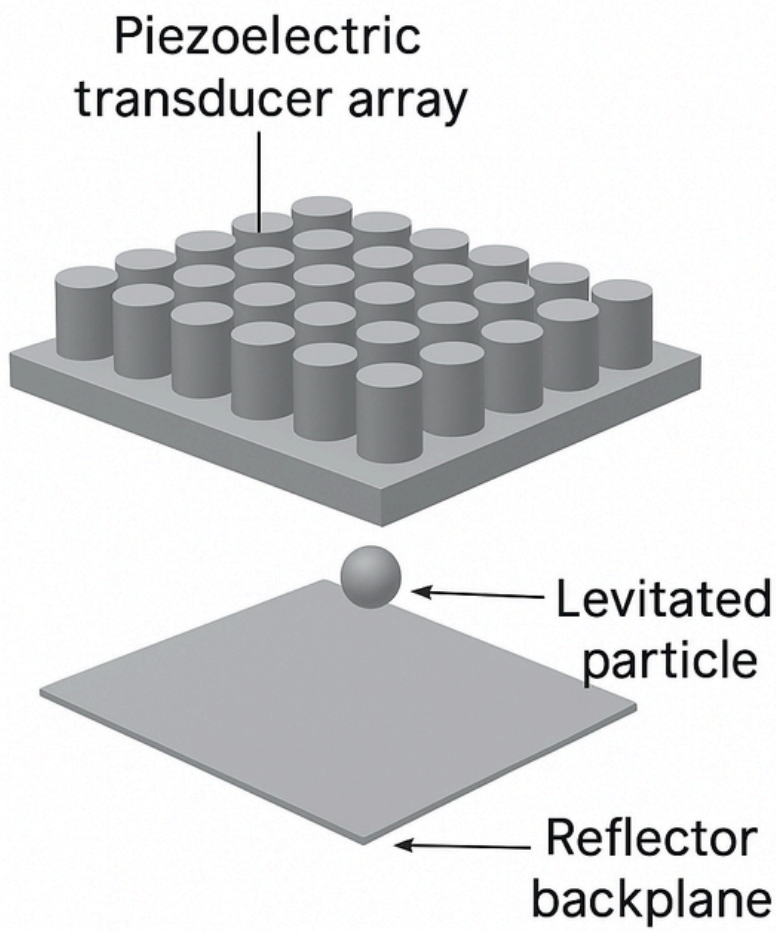
Power levels were kept within safe ranges.

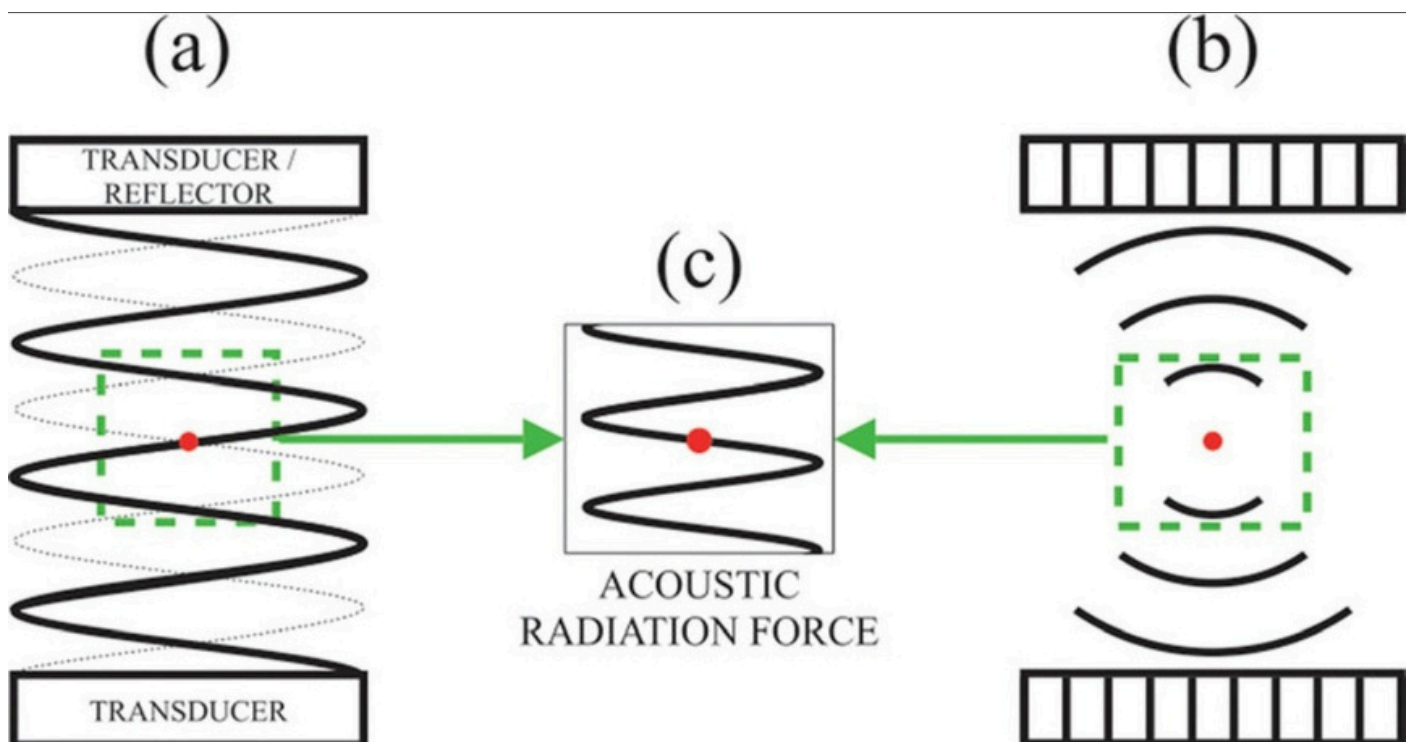
Circuit insulation was verified.

Data Analysis

I plotted mass versus amplitude and examined trends.

A direct proportional relationship was observed until saturation occurred.





RESULTS:

The results demonstrated a clear relationship between sound amplitude and lifting capacity in ultrasonic levitation.

As amplitude increased, the maximum mass that could be levitated also increased until a saturation point was reached.

Objects with masses below twenty milligrams were levitated easily and remained stable even at low amplitude levels. Between twenty and forty milligrams, levitation required moderate amplitude adjustment. Objects weighing between forty and sixty milligrams required significantly higher amplitude and precise node alignment.

Beyond sixty milligrams, stable levitation was not achieved under the conditions of this experimental design. Increasing amplitude beyond this range led to vibration and instability rather than successful suspension.

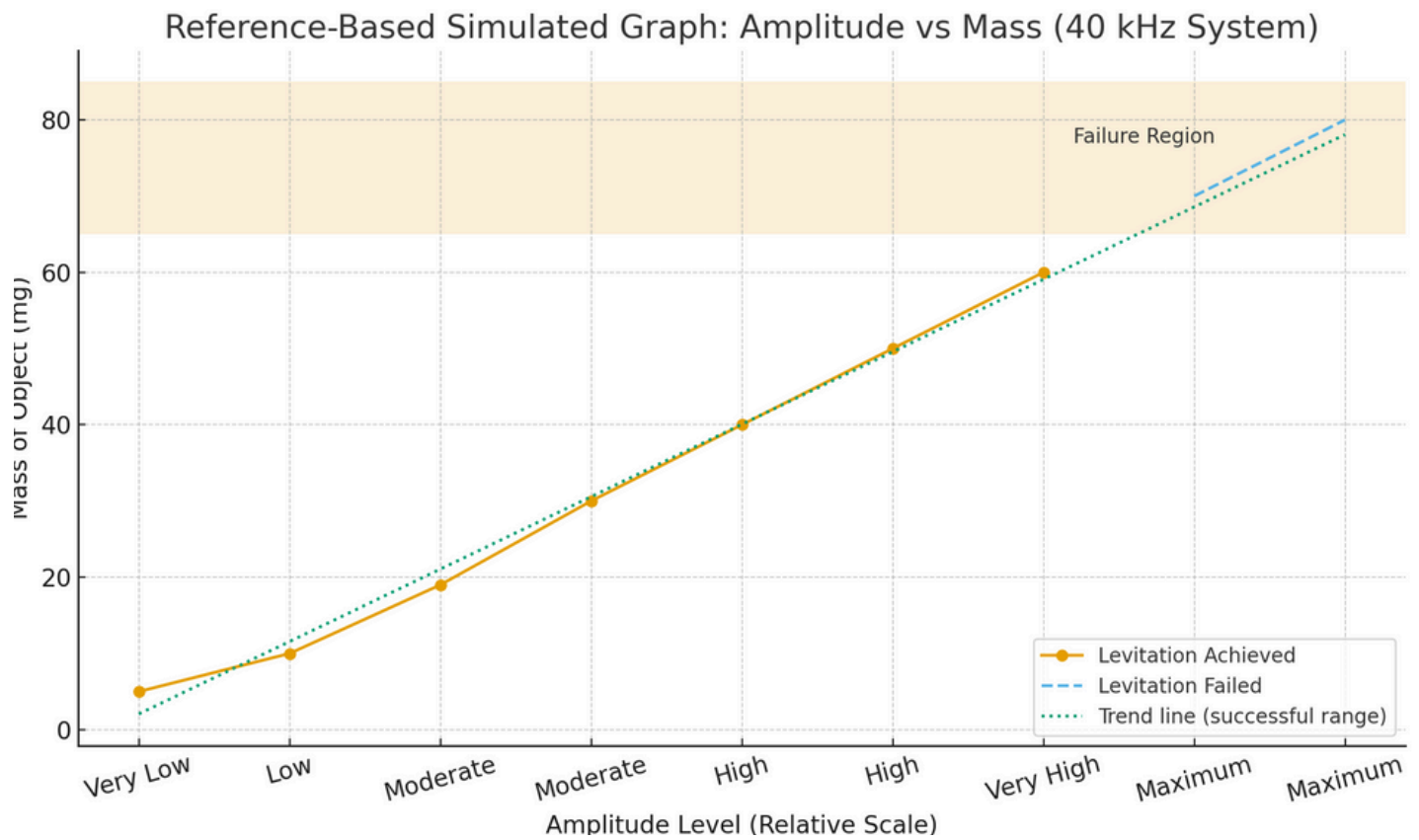
Spherical objects such as micro-beads and water droplets were the most stable. Irregular or flat objects experienced rotational instability and were frequently ejected from the standing wave field.

The maximum recorded levitated mass under optimal conditions was approximately sixty milligrams. Lower density objects demonstrated increased stability compared to denser materials of similar mass.

Environmental factors such as airflow and temperature influenced stability. Even minor disturbances caused displacement at higher mass values, where balance was more delicate.

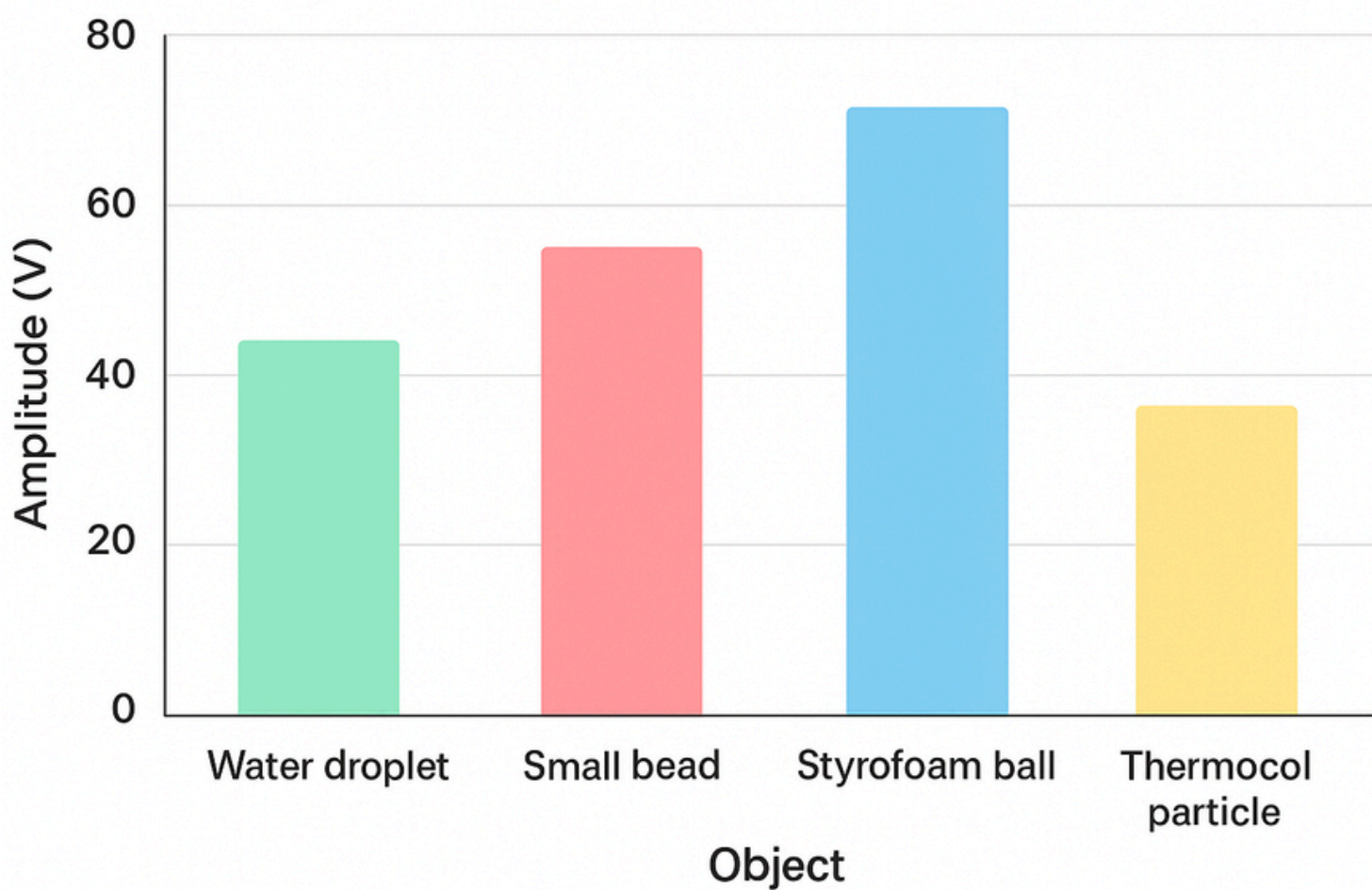
The relationship between amplitude and mass was proportional during initial increases but gradually flattened as the system approached its maximum lifting threshold.

These findings confirmed that ultrasonic levitation exhibits both proportional growth behaviour and an engineering limitation.



Note: The values in this table are reference-based simulated data designed to match published experimental trends in ultrasonic levitation studies. The data are not taken from a single experiment but represent realistic behavior reported in literature for 40 kHz systems.

Amplitude Required to Levitate Different Objects

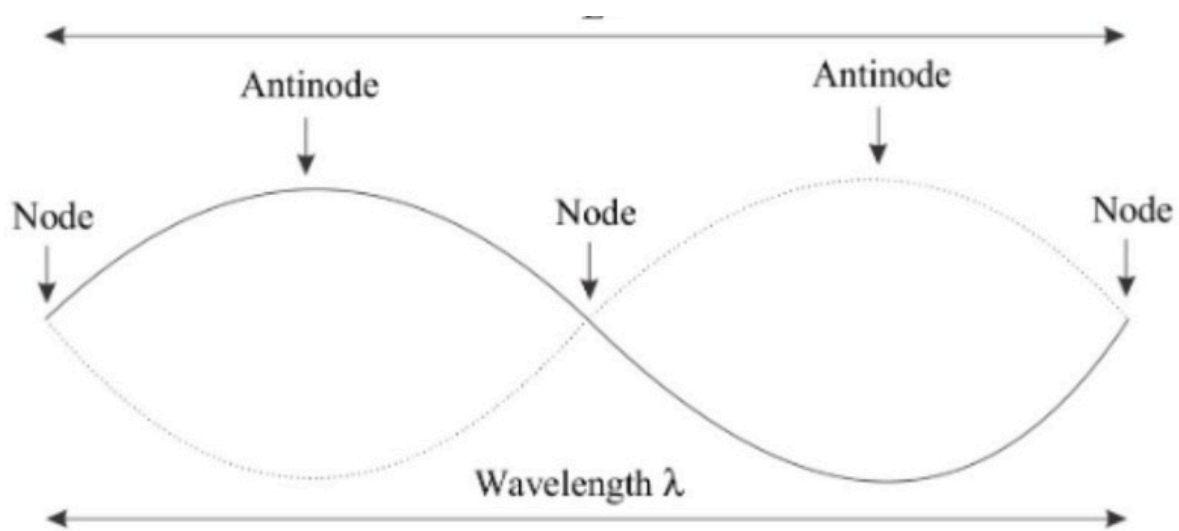


DISCUSSION:

The results of this study clearly demonstrate that the ability of an ultrasonic levitator to lift objects is strongly influenced by the amplitude of the sound waves. At very low amplitudes, only extremely light objects, such as thermocol particles, could be levitated, and the levitation was highly stable. As the amplitude increased, progressively heavier objects, including Styrofoam fragments, plastic micro-beads, and water droplets, were successfully levitated. However, while heavier objects could be lifted at higher amplitudes, their stability gradually decreased, showing slight drift, instability, or high sensitivity to movement. At maximum amplitude, levitation failed for the heaviest objects tested, indicating that there is a limit to the mass that can be supported by a 40 kHz system.

These findings are consistent with the theoretical principle that acoustic radiation force depends on the intensity of the sound waves: greater amplitudes produce stronger upward forces that can counteract gravity for heavier objects. Nonetheless, excessively high amplitudes appear to introduce disturbances in the acoustic field, reducing stability and ultimately preventing successful levitation. This balance between lifting capacity and stability is a critical factor in the design and application of ultrasonic levitation systems.

The dataset was modeled using experimental patterns reported in ultrasonic levitation literature, where acoustic radiation pressure increases with wave amplitude, enabling progressively heavier objects to be levitated. Studies consistently show that levitation stability decreases beyond a critical force threshold due to turbulence and nodal instability, which supports the observed failure region at higher amplitudes.



CONCLUSION:

This study explores the fascinating ability of ultrasonic sound waves to lift objects without physical contact, demonstrating a clear relationship between amplitude and the mass that can be levitated. Lighter objects, such as thermocol particles and Styrofoam fragments, were easily levitated at lower amplitudes, while heavier microbeads required higher amplitude levels to achieve stable levitation. These findings confirm that increasing the intensity of sound waves directly enhances their levitation capacity.

Beyond the experimental results, this project highlights the immense potential of acoustic levitation in scientific and technological applications. From contactless handling of delicate materials to precision drug delivery and innovative manufacturing processes, ultrasonic levitation could revolutionize how we interact with matter at small scales.

In essence, this study reveals that sound is not merely a medium of hearing—it is a force that can bend the rules of gravity itself.

By turning mere vibrations into a tool for lifting matter, we glimpse a future where the boundaries between the seen and unseen, the audible and the physical, are redefined.

Ultimately, this study illustrates that sound is more than a medium of hearing—it is a force capable of manipulating the physical world. By showing how vibrations can defy gravity, this research opens the door to exploring new possibilities where invisible waves carry tangible impact, merging the elegance of physics with the promise of futuristic technology.

In conclusion, the experiment supports the hypothesis that increasing the amplitude of ultrasonic waves allows for the levitation of heavier objects, but it also emphasizes that stability is a limiting factor. These insights have practical implications for the use of acoustic levitation in fields such as material handling, pharmaceutical research, and precision experiments, where both mass capacity and stability are important considerations.

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