PHY 224 Practical Physics

Ultrasonic Waves in Water

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Introduction:

The light from the sodium lamp possess the property of light in which interference occurs. Wavelength of the light source in a diffraction could be described as:

$$m \cdot \lambda = d \cdot \sin\theta \tag{1}$$

Where m is the order of maxima, ƛ is the wavelength of the light source, d is the width of the slit, and θ is the angle between central maxima and the maxima that is being measured.

As sound waves pass through liquid, pressure nodes and antinodes will behave like slits, and light will be refracted if it is traveling perpendicular to the sound direction. The speed of sound in a medium could be calculated as:

$$v_s = \sqrt{\frac{B}{\rho}} \tag{2}$$

Where B is the Bulk Modulus of water, v_s is velocity of sound underwater, ρ is the density for water, and it's 997 kg/m^3 under room temperature 25 °C. The diffraction grating provided has 2500 lines per inch, distance between diffraction grating lines is:

$$d = \frac{0.0254}{2500} = 1.016 \cdot 10^{-5} \text{ m (1 inch = 0.0254 m)} \tag{3}$$

The digital angle reading has a resolution up to 0.00225°, and considering human error in reading the error, 0.005° is used for the angle measurement uncertainty.

Purpose:

To determine the bulk modulus of water, and velocity of sound in water.

Materials:

Spectrometer, diffraction grating, sodium lamp, rotating table, spectroscope, digital angle reader, water cell, ultrasound transducer, oscilloscope, generator box, frequency counter, oscillator.

Procedure:

First, the ultrasound transducer and the oscillator were connected through the generator box, and the oscilloscope to the frequency counter. The ultrasonic beam was switched on and the interference beams from the diffraction grating was used in front of the sodium lamp to test the sodium lamp's wavelength, then the interference beams from the sodium lamp through the water were observed with different frequencies sent through the water and read on the oscilloscope from a range of 1.80 MHz to 2.1 MHz. The interference patterns were lined up as best humanly possibly through the spectroscope lens, lining up the center of the **X** with the middle of the interference lines, starting from the strongest, center point of interference and progressing outwards with equal numbers of interference lines on either side of the initial line, where the initial line was strongest in luminosity, and faded as the ± of the lines increased. The angles of these lines from the digital angle reader were recorded, and this procedure was repeated with each increasing frequency sent through the water cell. The frequencies were plotted, and velocity of the ultrasonic waves through the water was calculated (discussion).

Data:

Data for angle of diffraction using diffraction grating, sound frequency used and angle of diffraction using sound wave could be found in file 'grating.txt', 'frequency.txt' and 'water.txt' respectively.

Analysis/Discussion:

Substituting data into equation 1, the wavelength of sodium lamp can be calculated for each measurement. The final wavelength of sodium lamp is calculated by taking the average of all four calculations, which results 606 ± 1 nm. This result is 2.6 % higher than literature value 589 nm.

Seven measurements were made for diffraction of light using different sound frequencies as follows:

1.80001532 MHz, 1.84989124 MHz, 1.90003519 MHz, 1.95385781 MHz, 1.99891536 MHz, 2.05212394 MHz, and 2.10002201MHz.

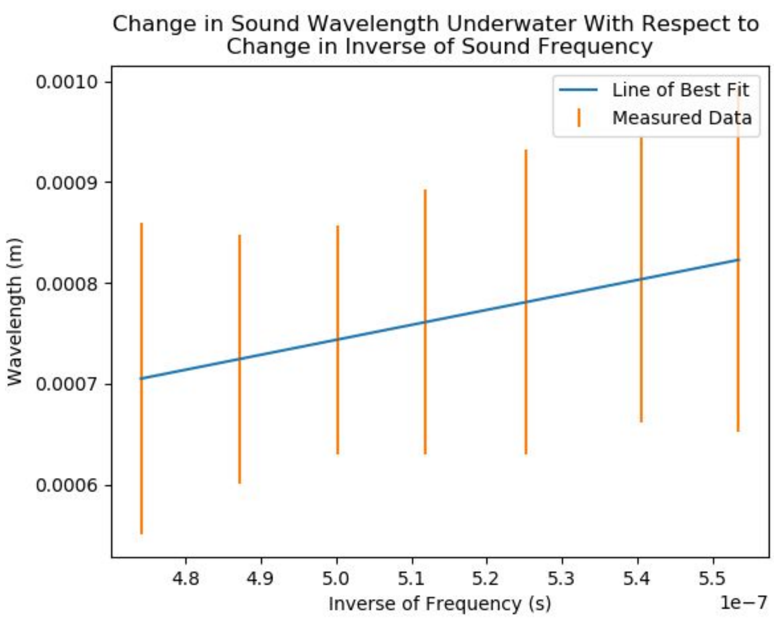

Figure 1: Change in sound wavelength underwater with respect to change in inverse of sound frequency

The velocity of sound in water was calculated to be $1.5 \cdot 10^3 \pm 0.7 \cdot 10^3\ m/s$, and by using *equation 2*, the bulk modulus of water is calculated to be 2 ± 1 GN/m2.

Chi-squared for these two variables were calculated to be 0.0793. The reason for such a small value of chi-squared is due to the error of the measurements being too large compared with angle of diffraction underwater. The accuracy of the result could be improved if the instrument was able to measurement by upgrading the equipment used, such as if there were a more precise way of lining up the spectroscope to the interference lines.

Conclusion:

The literature value for bulk modulus of water is $2.2 \cdot 10^9 N/m^2$, which falls within the range of experimental measurement, meaning that the bulk modulus of water within the experimental set-up is agreed with that of the expected value. The velocity of water through the cell was calculated to be $1.5 \cdot 10^3 \pm 0.7 \cdot 10^3\ m/s$, which is consistent with the expected 1500 m/s, varying with temperature slightly.

Reference:

(https://www.engineeringtoolbox.com/water-density-specific-weight-d_595.html)

(http://www.lamptech.co.uk/Documents/SO%20Spectral.htm)

(https://en.wikipedia.org/wiki/Bulk_modulus)

(https://van.physics.illinois.edu/qa/listing.php?id=12487&t=velocity-of-sound-in-water)