Variation in refractive index of sugar solution with concentration using Newton's rings

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ABSTRACT

Refractive index or index of refraction is an important physiochemical property of an optical medium. Here we report its value for sugar solution of various concentrations (0%, 5%, 10% and 20%) using the Newton's rings set up for yellow light from sodium lamp (λ=5893Å). Newton's Rings are an interference pattern generated via division of amplitude principle. The set-up used in our study is easily available in an undergraduate laboratory. The study correctly presents effect of increasing number of particles in a liquid on its refractive index.

KEY WORD*: Newton's Rings, refractive index, interference and sugar solution.*

INTRODUCTION

Refractive index of a medium relates how quickly the light passes through that medium. ($\mu = \frac{c}{v}$). Here c is velocity of light in vacuum and v is velocity of light in the said medium. It is dimensionless quantity whose value can be used as measure of purity or concentration of a solution. There are various refractometers available to measure refractive index of an optical medium [1]. But instead in our study we have measured refractive index of various samples using Newton's rings set up [2]. This is fairly simple experimental set up used in undergraduate laboratories to measure wavelength of incident light and to measure refractive index of water and various other liquids.

Newton's rings are an interference pattern generated via division of amplitude principle. The light reflected from the top and the bottom layer of the thin film (of desired liquid) trapped between the plano-convex lens and a plane glass plate interferes to give an interference pattern in form of concentric, alternate bright and dark fringes known as Newton's rings [3].

EXPERIMENTAL TECHNIQUE:

Apparatus: The measurements were carried on Omega type ES-249 experimental setup for Newton's rings [4] depicted in figure 1. It is a standard set up available in an undergraduate laboratory for measuring wavelength of incident light. The apparatus comprises of a travelling microscope with 30 X magnification. The microscope is focused with the help of rack and pinion arrangement. The longitudinal movement of the microscope saddle to observe the entire Newton's rings pattern is done by rotating the graduated drum, which has 100 divisions. The main scale for longitudinal motion of microscope moves 1mm on one rotation of the drum giving least count of 0.01 mm for our measurements. The wedge-shaped air film trapped between the optically flat glass plate and a plano-convex lens (radius of curvature = 1250 mm), rests inside a metal case placed under the microscope. An adjustable reflector plate is provided as part of the set up. Apart from the above mentioned, the apparatus also includes a yellow light source with 35-watt sodium lamp.

Procedure: The metal case containing the plano-convex lens and the glass plate is opened and few drops of the liquid to be studied are introduced on top of the glass plate. As the plano-convex lens is placed on top of the glass plate with convex side touching the plate, a thin wedge shaped film of desired liquid is formed between the two. The film formed is of uniform thickness and it is ensured that it does not contain any trapped air bubbles.

1. Air film: First Newton's rings interference pattern for air film was studied. The pattern obtained was in shape of concentric rings comprising of alternate dark and bright fringes. The central fringe was dark due to zero thickness of air film at point of contact of the plano-convex lens and the glass plate. Diameters of 2^{nd}, 4^{rth}, 6^{th}, 8^{th} … up to 20^{th} dark rings were noted using the longitudinal motion of the travelling microscope. The drum was always moved in single direction to avoid back lash error.
2. Consequently the air film was replaced by water, 5% sugar solution, 10% sugar solution and 20% sugar solution. A very clear Newton's rings interference pattern with dark zero order ring was observed for all the above mentioned cases. Diameter of 2^{nd} to 20^{th} ring was noted for the Newton's rings pattern obtained from respective films.
3. The refractive index 'μ' for a liquid using Newton's rings method can be calculated using the relation [2] -

$$\mu\ (of\ liquid) = \frac{\left(D_{n+p}^2 - D_n^2\right) for\ air}{\left(D_{n+p}^2 - D_n^2\right) for\ liquid}$$

$$D_n^2 = 4n\lambda R$$

Here D_{n+p} represents diameter of $(n+p)^{th}$ dark ring and D_n represents diameter of n^{th} dark ring for the respective medium. R, the radius of curvature of the plano-convex lens and λ the wavelength of the incident light from the sodium lamp are both constants for a given set up, so do not appear in the expression for μ. Also, n = 2, 4, 6, 8,...18 is order of interference and p is an even number of one's choice. We have taken p = 2. As the least count of the set-up for the longitudinal motion of the travelling microscope is 0.01 mm, we report the value of μ only up to three significant numbers.

RESULTS AND DISCUSSIONS:

Observations in form of plots are shown in figure 2 for couple of liquid films on which the Newton's rings experiment was performed. It can be clearly observed from the plot that the Newton's rings pattern shrinks, that is the rings come closer and the pattern becomes denser as one move towards higher concentrations. Just for check on our set up we also measured refractive index of full fat milk which was calculated to be 1.46, which is close match to the value reported in [5,6]. The refractive index for four samples water (0% concentration), 5%

sugar solution, 10% sugar solution and 20% sugar solution was calculated by observing the Newton's rings interference pattern.

Table 1 lists results from our measurements. Also we have summarized our results in figure 3.

Fig.1: Newton's rings set up.

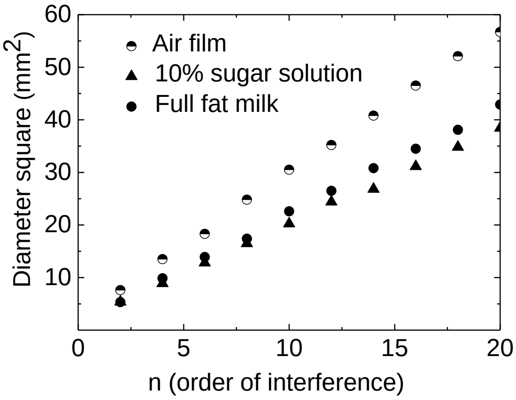

Fig. 2: A plot of square of diameter of interference fringes versus order of the interference for various mediums.

Medium	Refractive index
Air	1
Water	1.32
5% sugar solution	1.33
10% sugar solution	1.34
20% sugar solution	1.36

Table 1: Refractive index of various mediums.

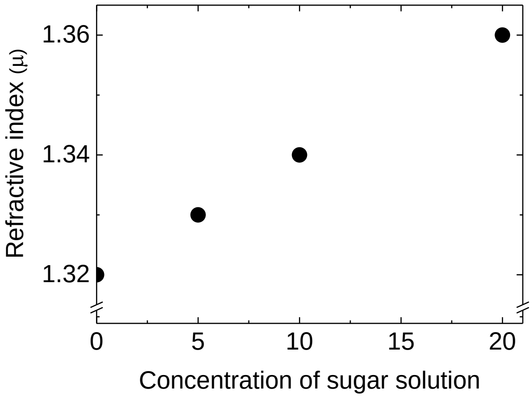

Fig. 3: Refractive index of sugar solutions as a function of concentration.

We can see from the graph that the refractive index of a sugar solution increases linearly as function of concentration of sugar. The increase in refractive index is due to increase in density of particles in the solution. More the concentration of sugar particles in a sample more will be the scattering of light, resulting in lowering of velocity of light which in turn increases the refractive index of the sugar solution We quote here one previous report [7] on refractive index of sugar solution for He-Ne laser light source just for comparison.

CONCLUSION

The above experiment can be performed in an undergraduate laboratory with ease. Mostly our undergraduate laboratory courses include Newton's rings experiment with the aim to either determine the wavelength of the given light source or to determine the refractive index of water. The experiment reported here uses the already available set up to broaden the understanding of an undergraduate student on the concept of refractive index. As it correctly depicts increase in refractive index with increase in concentration of solute in a liquid medium. The experiment can be further extended to study of refractive index of various available samples of milk which will reflect on its purity and so on.

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REFERENCES

1. Fardad Koohyar, Journal of thermodynamic catalysis, 2012, Vol 4(2), e117.
2. "A textbook of optics", N Subrahmanyam, Brij Lal, M N Avadhanulu, S Chand publications, 2012, 25th edition.
3. "Optics", Ajoy Ghatak, Tata Mcgraw Hill publication, 1991, 3rd Edition, 13.16
4. http://www.omegaelectronics.net/productlist.php?search=ES-249
5. "Studies on the refractive index of milk", K S Rangappa**,** Proceedings of the Indian Academy of Sciences - Section B, 1947, Volume 25, Issue 4, pp 86–94
6. A K Jaaskelainen, K E Peiponen, J A Raty, Journal of dairy science, 2001 1: Vol 84, 38-43.
7. W Mahmood bin Mat Yunus and Azizan bin Abdul Rahman, Applied Optics, 1988 Vol 27(16), 3341-3.