Refractive Index: A Tool to Investigate the Optical Properties of Common Liquids

Submitted by

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In partial fulfilment of the requirement of award of Bachelor Degree of science in Physics.

ST. TERESA'S COLLEGE (AUTONOMOUS)
ERNAKULAM
2025-26

ST. TERESA'S COLLEGE (AUTONOMOUS)

ERNAKULAM

CERTIFICATE

This is to certify that the project report entitled "**Refractive Index: A Tool to Investigate the Optical Properties of Common Liquids**" is an authentic work done by VAISHNAVI S R, St Teresa's College, Ernakulam, under our supervision at Department of Physics, St. Teresa's College, Ernakulam, for the partial requirements for the award of Degree of Bachelor of Science in Physics during the academic year 2025-26. The work presented in this dissertation has not been submitted for any other degree in this or any other university.

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ST. TERESA'S COLLEGE (AUTONOMOUS)
ERNAKULAM

B.Sc. PHYSICS
PROJECT REPORT

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YEAR OF WORK : 2025-26

This is to certify that this project work entitled, "**Refractive Index: A Tool to Investigate the Optical Properties of Common Liquids**" is an authentic work done by VAISHNAVI S R

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Submitted for the University examination held at St. Teresa's College, Ernakulam.

DATE: 16.04.26

EXAMINER: 1. ATHIRA PRAKASH

2.

DECLARATION

I, **VAISHNAVI S R,** final year B.Sc. Physics students of the Department of Physics and Centre for Research, St. Teresa's College (Autonomous), Ernakulam, do hereby declare that the project work entitled **"REFRACTIVE INDEX: A TOOL TO INVESTIGATE THE OPTICAL PROPERTIES OF COMMON LIQUIDS"** has been originally carried out by me under the guidance and supervision of **Dr. Susan Mathew**, Assistant Professor, Department of Physics, St. Teresa's College (Autonomous), Ernakulam, in partial fulfilment of the requirements for the award of the degree of Bachelor of Science in Physics. This project focuses on the experimental determination of the refractive index of common liquids and the analysis of their optical properties using standard laboratory methods. I further declare that this work has not been submitted either in part or in full for the award of any other degree or diploma in any institution. The data presented in this project are true and accurate to the best of my knowledge and belief.

PLACE: Ernakulam

DATE:

ACKNOWLEDGEMENT

I express my sincere gratitude to all those who have supported and guided me in the successful completion of my project titled "**REFRACTIVE INDEX: A TOOL TO INVESTIGATE THE OPTICAL PROPERTIES OF COMMON LIQUIDS.**"

First and foremost, I thank the Lord Almighty for His abundant blessings, strength, and guidance throughout the course of this work.

I extend my heartfelt thanks to Dr. Susan Mathew, Assistant Professor, Department of Physics and Centre for Research, St. Teresa's College (Autonomous), Ernakulam, for her constant encouragement, valuable guidance, and constructive suggestions during the experimental investigation of refractive index and the analysis of the optical properties of common liquids. Her regular supervision and insightful feedback greatly contributed to the successful completion of this project.

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Finally, I gratefully acknowledge everyone who directly or indirectly helped me in completing this project successfully.

ABSTRACT

Liquids play an important role in our daily life and are widely used in household, food, and sanitary applications. The optical properties of liquids, especially the refractive index, provide valuable information about their composition, purity, and concentration. Measurement of refractive index is therefore useful in physics, chemistry, and quality analysis of commonly used liquids.

Refractive Index is a fundamental optical parameter that describes how light propagates through a medium. It depends on the nature of the liquid and varies from one liquid to another. Even small changes in composition, such as the presence of dissolved substances or impurities, can cause noticeable changes in the refractive index.

In the present project, the refractive index of different categories of commonly used liquids has been determined using simple optical methods. The liquids selected for this study include edible liquids (oil and vinegar), aqueous solutions (salt water and sugar water), and sanitary liquids (hand sanitizer and other hygienic liquids). These liquids were chosen because of their widespread daily use and easy availability.

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CHAPTER 1
INTRODUCTION

Light is one of the most fundamental tools used in physics to study the nature of materials. When light travels from one medium into another medium, its speed does not remain the same. Because of this change in speed, the direction of light also changes. This bending of light gives us useful information about the substance through which the light travels. One of the most important quantities used to describe this behaviour is called the refractive index.

The refractive index tells us how much a material slows down light compared to its speed in empty space. Different materials slow down light by different amounts, depending on their internal structure and composition. Because of this reason, refractive index can be used to study the optical nature of materials and also to compare different substances.

This concept is not only important in theory but also has many real-life uses. It is commonly used in laboratories, industries, and even in food quality testing. For example, refractive index can be used to check the purity of edible oils, determine the concentration of sugar solutions, and study chemical compositions. This makes refractive index a very useful and practical parameter.

In this project, the refractive indices of some common liquids such as vinegar, apple cider vinegar, coconut oil, sunflower oil, sanitizer, salt water, and sugar water were studied. These liquids were selected because they are easily available and widely used in everyday life. Studying such liquids makes the experiment more meaningful and easier to connect with real-world applications.

Different liquids have different densities and molecular arrangements. Because of this, each liquid bends lights differently. By measuring and comparing their refractive indices, we can understand how their internal properties affect the behaviour of light.

The main aim of this project is to experimentally determine and compare the refractive indices of these common liquids using spectrometer and liquid lens methods. This helps in linking theoretical optics with practical measurement techniques

1.1 Refractive Index

Refractive index is a key optical property of a material that explains how light bends or changes direction when it moves through that material. When the light moves from one material to another, like from air into water or glass, it slows down or speeds up because the materials have different optical densities. When light slows down or speeds up, it bends or shifts its path. The refractive index of a medium tells us how much slower light travels through it compared to when it's moving through empty space.

The refractive index basically shows how much a material bends or slows down light when it passes through. Materials with a higher refractive index slow light down more and bend it more, while those with a lower refractive index let light pass through more easily. This refractive index changes based on things like how dense the medium is, what its molecules are like, and what it's made of. People often use refractive index to understand how light behaves when it passes through different substances. It helps you figure out what materials you're dealing with, check how concentrated a solution is, and see if a liquid is pure.

In industries, refractive index measurements are used to check the quality of food products like oils and drinks, analyses chemical solutions, and help in making optical instruments. Then, the refractive index is a straightforward and useful way to get how light behaves when it passes through different materials.

1.2 Brief History of Refractive index

People have been studying how light bends, or refracts, for a very long time. Ancient Greek and Roman scholars first noticed that light bends when it passes through water and glass. The Greek mathematician Euclid looked into how light behaves and explained some of the basic ideas about reflection and vision. Later on, Claudius Ptolemy carried out experiments to see how light bends when it moves from one medium like air into another like water.

In the 17th century, the Dutch scientist Willebrord Snell made an important contribution to understanding refraction by studying how the angles of incidence and refraction of light relate to each other. His work eventually became well known in optics, but scientists like Isaac Newton and Christian Huygens made more progress in understanding the nature of light. Newton talked about light as particles to explain what happens with optics, but Huygens came up with the wave theory, which made it easier to understand things like refraction.

Over time, people came to see refractive index as an important factor in optics and material science. Thanks to modern optical tools like spectrometers and refractometers, measuring the refractive index accurately is now possible. Now the present life, refractive index is commonly used in scientific research, industrial testing, and technology, making it a basic idea when studying light and how materials interact with it.

1.3 Theory

In this project, the refractive index of different liquids is determined using optical methods such as the spectrometer with hollow prism arrangement and the liquid lens technique. The refractive index is an important optical parameter that describes how light propagates through a medium.

The refractive index of a medium is defined as the ratio of the velocity of light in vacuum to the velocity of light in the medium. It is expressed as:

$$n = \frac{c}{v}$$

where c is the velocity of light in vacuum and v is the velocity of light in the given medium. This relation shows that the refractive index depends on how much the medium slows down the propagation of light.

In the spectrometer hollow prism method, the refractive index of the liquid is determined by measuring the angle of the prism and the angle of minimum deviation produced by the liquid prism. Since the sides of the hollow prism are made of thin parallel glass plates, the deviation is mainly produced by the liquid inside the prism. The refractive index of the liquid is calculated using the relation:

$$n = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

where A is the angle of the prism and D is the angle of minimum deviation of light through the liquid prism.

The refractive index of the liquid is also determined using the liquid lens method. In this method, a liquid lens is formed and its focal length is measured. The focal length of the combination of convex lens and liquid lens is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

where f_1 is the focal length of the convex lens, f_2 is the focal length of the liquid lens, and F is the focal length of the combination. The radius of curvature of the liquid surface is determined, and the refractive index of the liquid is calculated using the relation

$$n = 1 + \frac{R}{f_2}$$

where R is the radius of curvature of the liquid surface and f_2 is the focal length of the liquid lens. In this experiment, the liquid lens is of plano-concave type, in which one surface is plane and the other surface is curved.

Thus, by using these optical relations and experimental measurements, the refractive index of different liquid samples can be determined and compared.

1.4 Adulteration of Common Liquids

Adulteration refers to the process of lowering the quality of a substance by adding inferior, cheaper, or harmful materials. Many commonly used liquids are vulnerable to adulteration for economic gain. Since adulteration alters the composition and density of liquids, it also affects their refractive index. Therefore, measurement of refractive index can help in identifying possible adulteration and quality variations.

1. Vinegar

Vinegar is commonly adulterated by excessive dilution with water or by the addition of synthetic acetic acid. Sometimes artificial coloring agents are also added to mimic natural vinegar. Dilution reduces the concentration of acetic acid, which changes its refractive index. Measuring refractive index helps determine whether the vinegar has the correct concentration.

2. Apple Cider Vinegar

Apple cider vinegar may be adulterated by mixing synthetic vinegar, diluted acetic acid, or caramel colouring to imitate natural fermentation. In some cases, cheaper fruit extracts are added. Since genuine apple cider vinegar contains natural acids and organic compounds, adulteration alters its optical properties, including its refractive index.

3. Coconut Oil

Coconut oil is often adulterated by mixing cheaper vegetable oils such as palm oil or mineral oil. Sometimes refined oils are mixed with pure virgin coconut oil. Such adulteration changes the density and composition of the oil, leading to variation in refractive index. Measurement of refractive index is widely used in the food industry to check oil purity.

4. Sunflower Oil

Sunflower oil may be adulterated with low-cost oils like palm oil, soybean oil, or even recycled cooking oil. Adulteration affects the fatty acid composition and optical properties of the oil. Since each oil has a slightly different refractive index, comparison with standard values can help detect impurities.

5. Sanitizer

Hand sanitizers may be adulterated by reducing alcohol concentration or replacing ethanol/isopropyl alcohol with cheaper industrial alcohols such as methanol, which is toxic. Some may also contain excess water. Such changes significantly affect both safety and refractive index. Optical methods can help identify abnormal variations in composition.

6. Sugar Water

Sugar solutions can be adulterated by adding artificial sweeteners or excessive water. Since the refractive index of sugar water increases with concentration, dilution reduces its refractive index. Thus, refractive index measurement is commonly used to determine sugar concentration in beverages and food products.

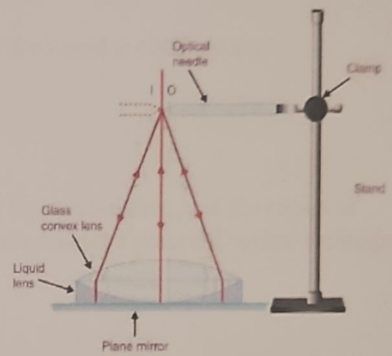
7. Salt Water

Salt water solutions may be altered by changing salt concentration. The refractive index increases with increasing salt concentration. Therefore, measuring refractive index helps in determining salinity and identifying improper dilution.

CHAPTER 2
EXPERIMENTAL METHODS

2.1 Liquid Lens

The liquid lens method is used to determine the refractive index of a liquid by studying its lens action. When a liquid is placed between glass surfaces, it forms a curved surface due to surface tension and behaves like a lens. In this experiment, the liquid lens formed is of plano–concave type, having one plane surface and one curved surface. This curved surface refracts light and produces an image.



When the liquid lens is combined with a convex lens, the focal length of the combination changes. The focal length of the liquid lens is determined from the focal length of the convex lens and the focal length of the combination. Using the lens maker's relation and the radius of curvature of the liquid surface, the refractive index of the liquid is calculated. Thus, by measuring focal lengths and radius of curvature, the refractive index of the liquid can be determined.

Let
f_1= focal length of the convex lens
F= focal length of the combination of convex lens and liquid lens
f_2= focal length of the liquid lens

When the convex lens and liquid lens are placed in contact, the focal length of the combination is given by the relation:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

From this, the focal length of the liquid lens is obtained as:

$$f_2 = \frac{F f_1}{f_1 - F}$$

To determine the refractive index of the liquid, the lens maker's relation is used. For a lens,

$$\frac{1}{f_2} = (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

Since the liquid lens is plano–concave, one surface is plane. Therefore, its radius of curvature is infinite ($R_2 = \infty$). Hence, the equation reduces to:

$$\frac{1}{f_2} = (n-1)\left(\frac{1}{R}\right)$$

where R is the radius of curvature of the curved surface.

The radius of curvature $R$of the convex lens surface is determined using **Boy's method**, given by:

$$R' = \frac{f_1 d}{f_1 - d}$$

where d is the distance of the object from the lens when a clear image is formed.
Since the liquid surface is in the opposite orientation, the radius of curvature of the liquid lens is

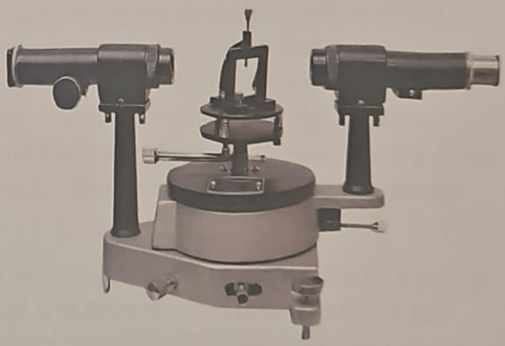
$$R = -R'$$

Substituting in the simplified lens maker's formula, the refractive index of the liquid is obtained as:

$$n = 1 + \frac{R}{f_2}$$

Thus, by measuring the focal length of the convex lens, the focal length of the combination, and the radius of curvature, the refractive index of the liquid can be determined. This method provides a practical optical technique for investigating the refractive index of liquids.

2.2 Spectrometer



The spectrometer is an optical instrument used to measure angles accurately. In this experiment, it is used to determine the refractive index of liquids using a hollow prism arrangement. The hollow prism consists of thin parallel glass plates, and the liquid is filled inside it. Since the glass plates are thin and parallel, the deviation produced by them is negligible. Therefore, the deviation of light is mainly due to the liquid inside the prism.

When a ray of monochromatic light passes through the liquid prism, it undergoes refraction at the two surfaces and emerges with a deviation. As the angle of incidence is varied, there exists a particular position at which the angle of deviation becomes minimum. This position is called the condition of minimum deviation.

Let
A= angle of the prism
D= angle of minimum deviation

The refractive index of the liquid is determined using the relation:

$$n = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

where A is the prism angle and D is the angle of minimum deviation for the liquid prism.

By measuring the prism angle and the corresponding angle of minimum deviation using the spectrometer, the refractive index of the liquid can be calculated. Thus, the spectrometer hollow prism method provides a precise and reliable optical technique for determining the refractive index of liquids.

CHAPTER 3
PROCEDURE

In this study, we chose some everyday liquids like vinegar, apple cider vinegar, coconut oil, sunflower oil, sanitizer, sugar water, and salt water to measure their refractive indices. These liquids were picked because they're easy to find and used a lot in daily life for cooking, health, hygiene, and around the house.

Every liquid has its own physical makeup and properties that change the way light moves through it. Measuring the refractive index of these liquids lets us see how they handle light and allows us to compare their optical properties.

Coconut oil and sunflower oil are everyday cooking oils people often use. Vinegar and apple cider vinegar show up in recipes and help keep food fresh. Sanitizer is key for keeping things clean, while sugar water and salt water are examples of solutions with varying amounts of dissolved stuff in them. By looking at the refractive index values of these liquids, we can get a better idea of how they behave optically and learn more about their physical properties. This experiment looks at the properties of common liquids by using simple optical methods.

3.1 Liquid Lens

In this experiment, the refractive index of the given liquids was determined using the liquid lens method. First, a plane mirror was placed horizontally on the base of a stand, and a convex lens was placed over the mirror. A sharp pointer was fixed vertically above the lens. The inverted image of the pointer formed by the convex lens was observed from above. The pointer was adjusted until the tip of the image coincided exactly with the tip of the pointer without parallax. The distance of the pointer tip from the top and bottom surfaces of the lens was measured, and their average value was taken as the focal length of the convex lens f_1. This procedure was repeated several times to obtain the mean focal length f_1.

Next, the convex lens was removed and a small drop of distilled water was placed on the plane mirror. The convex lens was then carefully placed over the water drop, forming a thin liquid lens between the convex lens and the mirror. The pointer was again adjusted until the image was obtained without parallax. The distances were measured as before, and their average value gave the focal length of the combination of convex lens and liquid lens F. From the relation

the focal length of the liquid lens f_2 was calculated.

To determine the radius of curvature of the convex lens surface, the lens was floated on mercury in a dish with one face in contact with mercury. The pointer was adjusted until the image coincided without parallax, and the distance was measured. Using the required relation, the radius of curvature R was calculated.

Using the values of R and f_2, the refractive index of water was determined using the relation

After determining the refractive index of water, the same procedure was repeated for the other given liquids such as vinegar, apple cider vinegar, coconut oil, sunflower oil, sanitizer, sugar water, and salt water. In each case, water was replaced by the respective liquid to form the liquid lens, and the focal length of the combination F was measured. Using the known the lens floated mercury d and convex lens f_1 as reference and the measured values of f_1, R and f_2, the refractive index of the other liquids was calculated.

Thus, the refractive index of the given liquids was determined by the liquid lens method and compared with that of water.

3.2 Spectrometer

Preliminary Adjustments

1. Focusing of the Eyepiece

The eyepiece of the telescope is first focused to obtain a clear view of the cross-wires. The telescope is directed towards a bright white surface or a well-illuminated background, and the eyepiece is rotated until the cross-wires appear sharp and distinct. This adjustment ensures that the eye is properly focused on the plane of the cross-wires and helps to avoid errors due to parallax during observations.

2. Adjustment of the Telescope

The telescope is then adjusted to receive parallel rays of light. It is directed towards a distant object, and the focusing screw is adjusted until a clear image of the object is seen without parallax. When the image and cross-wires are in the same plane, the image does not shift relative to the cross-wires when the eye is moved. This ensures that the telescope is properly focused for accurate measurement of angular positions.

3. Adjustment of the collimator

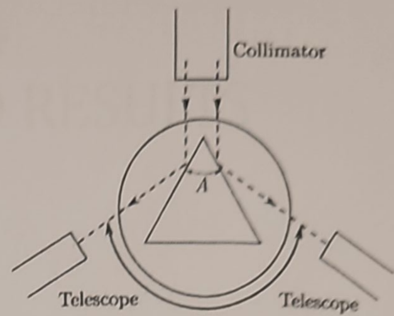
The slit of the collimator is illuminated using a sodium lamp and adjusted to obtain a narrow vertical slit. The telescope is aligned with the collimator, and the collimator lens is adjusted using the focusing screw until a sharp and well-defined image of the slit is observed through the telescope. The slit is made as narrow as possible to obtain a clear image. This adjustment ensures that parallel rays of light emerge from the collimator.

4. Adjustment of the Prism Table

The prism table is levelled using the levelling screws provided. The levelling is done so that the top surface of the prism table becomes horizontal. Proper levelling ensures that the prism placed on the table remains correctly aligned with the incident light. The levelling is checked by observing that the image of the slit remains properly aligned during rotation of the table.

In this experiment, the refractive index of the given liquid samples was determined using a spectrometer with a hollow prism arrangement. After completing the preliminary adjustments of the spectrometer, the hollow prism was placed on the prism table with its base resting on the table and properly levelled. The prism was oriented such that one of its refracting edges faced the collimator, and light from the collimator was allowed to fall on the prism.

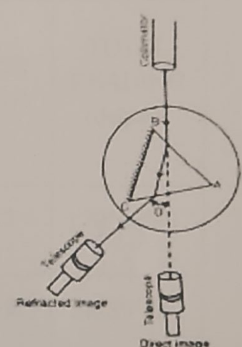
1) Determination of Angle of the Prism (A)



Initially, the angle of the hollow prism (A) was determined using the spectrometer. The prism was placed on the prism table with its base resting on the leveled surface and one of its refracting edges facing the collimator. The telescope was first aligned to observe the reflected image of the slit from one face of the prism. The telescope was adjusted so that the reflected image coincided exactly with the vertical cross-wire, and the corresponding angular reading was recorded using the vernier scale.

The telescope was then rotated to observe the reflected image from the second face of the prism. Again, the telescope was adjusted until the reflected image coincided with the cross-wire, and the angular reading was noted. The difference between the two readings was determined, and half of this value gave the angle of the prism (A). The procedure was repeated to obtain accurate readings, and the mean value of the prism angle was calculated.

2) Determination of Angle of Minimum Deviation (D)



After determining the prism angle, the hollow prism was filled with the given liquid sample such as vinegar, apple cider vinegar, coconut oil, sunflower oil, sanitizer, sugar water, or salt water. The prism was placed on the prism table so that light from the collimator passed through the liquid prism.

The telescope was rotated to observe the refracted ray emerging from the prism. The prism table was slowly rotated while observing the refracted image through the telescope. At a particular position, the refracted image was found to become stationary for a small rotation of the prism. This position corresponds to the condition of minimum deviation. The telescope was adjusted to coincide exactly with the refracted image, and the corresponding angular reading was recorded.

The observations were taken on both sides of the prism, and from these readings the angle of minimum deviation (D) was determined. The same procedure was repeated for each of the given liquid samples to obtain accurate results. Using the measured values of the prism angle (A) and the angle of minimum deviation (D), the refractive index of each liquid was calculated using the standard relation.

CHAPTER 4
OBSERVATIONS AND RESULTS

4.1 a) Spectrometer

Value of one main scale division (MSD) = $30°$

No. of divisions on the vernier = 60

Least count of the vernier = $30'$

i) Angle of the Prism (A)

READING OF	VERNIER 1			VERNIER 2		
	MSR (degree)	VSR (div)	TOTAL READING (degree)	MSR (degree)	VSR (div)	TOTAL READING (degree)
REFLECTED RAY OF FACE 1	$358°30'$	24	$358°42'$	$178°30'$	37	$178°48'30''$
REFLECTED RAY OF FACE 2	$238°30'$	22	$238°41'$	$58°30'$	19	$58°39'30''$
DIFFERENCE BETWEEN FACE 1 AND FACE 2			$120°1'$			$120°9'$

Mean Angle, $\theta = 120°5'$

$A = 180° - \theta = 180° - 120°5'$

Angle of the Prism, $A = 59°55'$

ii) Angle of the Minimum Deviation

❖ Sample A (Vinegar)

READING OF	VERNIER 1			VERNIER 2		
	MSR (degree)	VSR (div)	TOTAL READING (degree)	MSR (degree)	VSR (div)	TOTAL READING (degree)
REFRACTED RAY	9°30′	20	9°40′	189°	26	189°13′
DIRECT RAY	34°	30	34°15′	214′	36	214°18′
DIFFERENCE BETWEEN REFRACTED AND DIRECT RAY			24°35′			25°5′

Angle of the Prism, A = 59°55′

Mean, D = 24°50′

$$n = \frac{\sin(\frac{A+D}{2})}{\sin\left(\frac{A}{2}\right)} = 1.349$$

- Sample B (Apple Cider Vinegar)

READING OF	VERNIER 1			VERNIER 2		
	MSR (degree)	VSR (div)	TOTAL READING (degree)	MSR (degree)	VSR (div)	TOTAL READING (degree)
REFRACTED RAY	132°	18	132°9′	312°30′	40	312°20′
DIRECT RAY	158°	20	158°10′	338°	44	338°22′
DIFFERENCE BETWEEN REFRACTED AND DIRECT RAY			26°1′			26°2′

Angle of the Prism, A = 59°55

Mean, D = 26°1′30″

$$n = \frac{\sin(\frac{A+D}{2})}{\sin\left(\frac{A}{2}\right)} = 1.364$$

- Sample C (Coconut Oil)

READING OF	VERNIER 1			VERNIER 2		
	MSR (degree)	VSR (div)	TOTAL READING (degree)	MSR (degree)	VSR (div)	TOTAL READING (degree)
REFRACTED RAY	318°	16	318°8′	138°	22	138°11′
DIRECT RAY	350°30′	30	350°45′	170°30′	46	170°53′
DIFFERENCE BETWEEN REFRACTED AND DIRECT RAY			32°37′			32°42′

Angle of the Prism, A = 59°55′

Mean, D = 32°39′30″

$$n = \frac{\sin(\frac{A+D}{2})}{\sin\left(\frac{A}{2}\right)} = 1.447$$

- Sample D (Sunflower Oil)

READING OF	VERNIER 1			VERNIER 2		
	MSR (degree)	VSR (div)	TOTAL READING (degree)	MSR (degree)	VSR (div)	TOTAL READING (degree)
REFRACTED RAY	200°30′	35	200°47′30″	20°30′	23	20°41′30″
DIRECT RAY	235°	35	235°17′30″	55°30′	37	55°18′30″
DIFFERENCE BETWEEN REFRACTED AND DIRECT RAY			34°30′			34°37′

Angle of the Prism, A = 59°55′

Mean, D = 34°33′30″

$$n = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)} = 1.470$$

❖ Sample E (Sugar Water)

READING OF	VERNIER 1			VERNIER 2		
	MSR (degree)	VSR (div)	TOTAL READING (degree)	MSR (degree)	VSR (div)	TOTAL READING (degree)
REFRACTED RAY	301°	20	301°10′	121°	11	121°30′30″
DIRECT RAY	326°30′	31	326°45′30″	146°30′	31	146°45′30″
DIFFERENCE BETWEEN REFRACTED AND DIRECT RAY			25°35′30″			25°15′

Angle of the Prism, A = 59°55′

Mean, D = 25°25′15″

$$n = \frac{\sin(\frac{A+D}{2})}{\sin\left(\frac{A}{2}\right)} = 1.357$$

❖ Sample F (Salt Water)

READING OF	VERNIER 1			VERNIER 2		
	MSR (degree)	VSR (div)	TOTAL READING (degree)	MSR (degree)	VSR (div)	TOTAL READING (degree)
REFRACTED RAY	339°	10	339°30′	159°	11	159°30′30″
DIRECT RAY	4°	10	4°30′	189°	9	184°4′30″
DIFFERENCE BETWEEN REFRACTED AND DIRECT RAY			25°			24°34′

Angle of the Prism, A = 59°55′

Mean, D = 24°47′

$$n = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)} = 1.349$$

- Sample G (Sanitizer)

READING OF	VERNIER 1			VERNIER 2		
	MSR (degree)	VSR (div)	TOTAL READING (degree)	MSR (degree)	VSR (div)	TOTAL READING (degree)
REFRACTED RAY	346°	18	346°9′	166°	16	166°8′
DIRECT RAY	12°	10	12°30′	191°30′	39	191°49′30″
DIFFERENCE BETWEEN REFRACTED AND DIRECT RAY			26°21′			25°41′30″

Angle of the Prism, A = 59°55′

Mean, D = 26°1′15″

$$n = \frac{\sin(\frac{A+D}{2})}{\sin\left(\frac{A}{2}\right)} = 1.364$$

4.2 b) Liquid Lens

READING OF	DISTANCE OF POINTER FROM (cm)						MEAN (cm)
	TOP OF LENS			BOTTOM OF LENS			
	1	2	MEAN	1	2	MEAN	
CONVEX LENS (f_1)	20.4	20.5	20.45	20.5	20.6	20.55	20.50
COMBINATION WITH WATER (F)	29.4	29.5	29.45	29.8	29.9	29.85	29.65
LENS FLOATED IN MERCURY(d)	10.2	10.3	10.25	10.7	10.8	10.75	10.5

Mean focal length of the convex lens, $(f_1) = 20.50\ cm$

Focal length of the liquid lens, $f_2 = \frac{-Ff_1}{f_1} - F = -66.428\ cm$

Distance of the pointer from the lens floated in mercury when a clear image is formed, $d = 10.5\ cm$

Radius of curvature of the convex lens, $R' = \frac{f_1 d}{f_1} - d = 21.525\ cm$

Radius of curvature of the liquid lens, $R = R' = -21.525\ cm$

Refractive index of the water, $n = 1 + \frac{R}{f_2} = 1.3240$

- Sample A (Vinegar)

READING OF	DISTANCE OF POINTER FROM (cm)						MEAN (cm)
	TOP OF LENS			BOTTOM OF LENS			
	1	2	MEAN	1	2	MEAN	
CONVEX LENS (f_1)	20.4	20.5	20.45	20.5	20.6	20.55	20.50
COMBINATION WITH VINEGAR (F)	30.7	30.9	30.8	31.3	31.5	31.4	31.1
LENS FLOATED IN MERCURY(d)	10.2	10.3	10.25	10.7	10.8	10.75	10.5

Mean focal length of the convex lens, $(f_1) = 20.50\ cm$

Focal length of the liquid lens, $f_2 = \frac{-Ff_1}{f_1} - F = -60.146\ cm$

Distance of the pointer from the lens floated in mercury when a clear image is formed, $d = 10.5\ cm$

Radius of curvature of the convex lens, $R' = \frac{f_1 d}{f_1} - d = 21.525\ cm$

Radius of curvature of the liquid lens, $R = R' = -21.525\ cm$

Refractive index of the vinegar, $n = 1 + \frac{R}{f_2} = 1.357$

- Sample B (Apple Cider Vinegar)

READING OF	DISTANCE OF POINTER FROM (cm)						MEAN (cm)
	TOP OF LENS			BOTTOM OF LENS			
	1	2	MEAN	1	2	MEAN	
CONVEX LENS (f_1)	20.4	20.5	20.45	20.5	20.6	20.55	20.50
COMBINATION WITH APPLE CIDER VINEGAR (F)	31.2	31.3	31.25	32.7	32.8	32.75	32
LENS FLOATED IN MERCURY(d)	10.2	10.3	10.25	10.7	10.8	10.75	10.5

Mean focal length of the convex lens, $(f_1) = 20.50\ cm$

Focal length of the liquid lens, $f_2 = \frac{-Ff_1}{f_1} - F = -57.043\ cm$

Distance of the pointer from the lens floated in mercury when a clear image is formed, $d = 10.5\ cm$

Radius of curvature of the convex lens, R' = $\frac{f_1 d}{f_1} - d = 21.525\ cm$

Radius of curvature of the liquid lens, $R = R' = -21.525\ cm$

Refractive index of the apple cider vinegar, n = $1 + \frac{R}{f_2} = 1.377$

- Sample C (Coconut Oil)

READING OF	DISTANCE OF POINTER FROM (cm)						MEAN (cm)
	TOP OF LENS			BOTTOM OF LENS			
	1	2	MEAN	1	2	MEAN	
CONVEX LENS (f_1)	20.4	20.5	20.45	20.5	20.6	20.55	20.50
COMBINATION WITH COCONUT OIL (F)	35.6	35.7	35.65	36	36.1	36.05	35.85
LENS FLOATED IN MERCURY(d)	10.2	10.3	10.25	10.7	10.8	10.75	10.5

Mean focal length of the convex lens, $(f_1) = 20.50\ cm$

Focal length of the liquid lens, $f_2 = \frac{-Ff_1}{f_1} - F = -47.877\ cm$

Distance of the pointer from the lens floated in mercury when a clear image is formed, $d = 10.5\ cm$

Radius of curvature of the convex lens, $R' = \frac{f_1 d}{f_1} - d = 21.525\ cm$

Radius of curvature of the liquid lens, $R = R' = -21.525\ cm$

Refractive index of the coconut oil, $n = 1 + \frac{R}{f_2} = 1.449$

- Sample D (Sunflower Oil)

READING OF	DISTANCE OF POINTER FROM (cm)						MEAN (cm)
	TOP OF LENS			BOTTOM OF LENS			
	1	2	MEAN	1	2	MEAN	
CONVEX LENS (f_1)	20.4	20.5	20.45	20.5	20.6	20.55	20.50
COMBINATION WITH SUNFLOWER OIL (F)	36.1	36	36.05	37.4	37.6	37.5	36.775
LENS FLOATED IN MERCURY(d)	10.2	10.3	10.25	10.7	10.8	10.75	10.5

Mean focal length of the convex lens, $(f_1) = 20.50\ cm$

Focal length of the liquid lens, $f_2 = \frac{-Ff_1}{f_1} - F = -46.321\ cm$

Distance of the pointer from the lens floated in mercury when a clear image is formed, $d = 10.5\ cm$

Radius of curvature of the convex lens, $R' = \frac{f_1 d}{f_1} - d = 21.525\ cm$

Radius of curvature of the liquid lens, $R = R' = -21.525\ cm$

Refractive index of the sunflower oil, $n = 1 + \frac{R}{f_2} = 1.464$

- Sample E (Sugar Water)

READING OF	DISTANCE OF POINTER FROM (cm)						MEAN (cm)
	TOP OF LENS			BOTTOM OF LENS			
	1	2	MEAN	1	2	MEAN	
CONVEX LENS (f_1)	20.4	20.5	20.45	20.5	20.6	20.55	20.50
COMBINATION WITH SUNFLOWER OIL (F)	31	31.2	31.1	31.7	31.4	31.55	31.325
LENS FLOATED IN MERCURY(d)	10.2	10.3	10.25	10.7	10.8	10.75	10.5

Mean focal length of the convex lens, $(f_1) = 20.50\ cm$

Focal length of the liquid lens, $f_2 = \frac{-Ff_1}{f_1} - F = -59.322\ cm$

Distance of the pointer from the lens floated in mercury when a clear image is formed, $d = 10.5\ cm$

Radius of curvature of the convex lens, $R' = \frac{f_1 d}{f_1} - d = 21.525\ cm$

Radius of curvature of the liquid lens, $R = R' = -21.525\ cm$

Refractive index of the sugar water, $n = 1 + \frac{R}{f_2} = 1.362$

- Sample F (Salt Water)

READING OF	DISTANCE OF POINTER FROM (cm)						MEAN (cm)
	TOP OF LENS			BOTTOM OF LENS			
	1	2	MEAN	1	2	MEAN	
CONVEX LENS (f_1)	20.4	20.5	20.45	20.5	20.6	20.55	20.50
COMBINATION WITH SUNFLOWER OIL (F)	30.8	31.1	30.95	31.4	31.5	31.45	31.2
LENS FLOATED IN MERCURY(d)	10.2	10.3	10.25	10.7	10.8	10.75	10.5

Mean focal length of the convex lens, $(f_1) = 20.50\ cm$

Focal length of the liquid lens, $f_2 = \frac{-Ff_1}{f_1} - F = -59.775\ cm$

Distance of the pointer from the lens floated in mercury when a clear image is formed, $d = 10.5\ cm$

Radius of curvature of the convex lens, $R' = \frac{f_1 d}{f_1} - d = 21.525\ cm$

Radius of curvature of the liquid lens, $R = R' = -21.525\ cm$

Refractive index of the salt water, $n = 1 + \frac{R}{f_2} = 1.360$

- Sample G (Sanitizer)

READING OF	DISTANCE OF POINTER FROM (cm)						MEAN (cm)
	TOP OF LENS			BOTTOM OF LENS			
	1	2	MEAN	1	2	MEAN	
CONVEX LENS (f_1)	20.4	20.5	20.45	20.5	20.6	20.55	20.50
COMBINATION WITH SANITIZER (F)	30.8	30.9	30.85	31.2	31.3	31.25	31.05
LENS FLOATED IN MERCURY(d)	10.2	10.3	10.25	10.7	10.8	10.75	10.5

Mean focal length of the convex lens, $(f_1) = 20.50\ cm$

Focal length of the liquid lens, $f_2 = \frac{-Ff_1}{f_1} - F = -60.334\ cm$

Distance of the pointer from the lens floated in mercury when a clear image is formed, $d = 10.5\ cm$

Radius of curvature of the convex lens, $R' = \frac{f_1 d}{f_1} - d = 21.525\ cm$

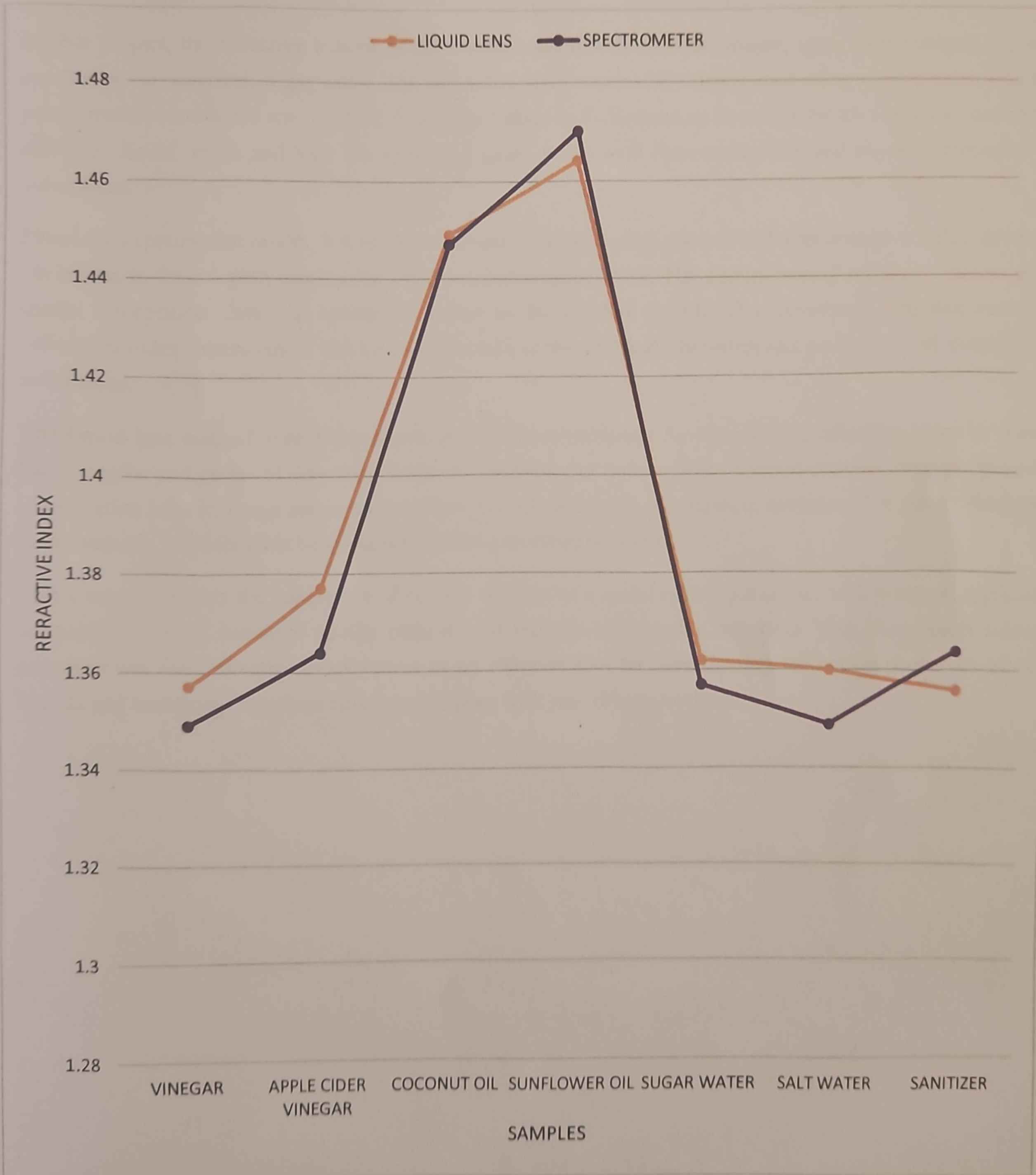
Radius of curvature of the liquid lens, $R = R' = -21.525\ cm$

Refractive index of the sanitizer, $n = 1 + \frac{R}{f_2} = 1.356$

REFRACTIVE INDEX OF COMMON LIQUIDS FORMED BY SPECTROMETER AND LIQUID LENS

SAMPLES	REFRACTIVE INDEX OF	
	LIQUID LENS	SPECTROMETER
VINEGAR	1.357	1.349
APPLE CIDER VINEGAR	1.377	1.364
COCONUT OIL	1.449	1.447
SUNFLOWER OIL	1.464	1.470
SUGAR WATER	1.362	1.357
SALT WATER	1.360	1.349
SANITIZER	1.356	1.364

GRAPH COMPARING REFRACTIVE INDEX VALUES FROM SPECTROMETER AND LIQUID LENS



CHAPTER 5
CONCLUSION

In this project, the refractive indices of commonly used liquids such as vinegar, apple cider vinegar, coconut oil, sunflower oil, sanitizer, sugar water, and salt water were successfully determined using spectrometer with hollow prism method and liquid lens method. The study helped in understanding how light behaves when it passes through different liquid media and how the refractive index varies with the composition and physical properties of the substances.

From the experimental results, it was observed that different liquids showed different refractive index values due to variations in their density, molecular structure, and concentration. The comparison of refractive indices provided useful information about the optical behaviour of the selected liquids. The experiment also demonstrated that refractive index measurement can be used to analyse the physical characteristics and quality of commonly used substances.

The liquid lens method provided a simple and effective technique for determining refractive index by measuring focal lengths and radius of curvature, while the spectrometer hollow prism method enabled accurate determination of refractive index through measurement of prism angle and angle of minimum deviation. The results obtained from both methods were found to be consistent within experimental limits.

This study highlights the importance of refractive index as a useful optical parameter with practical applications in scientific research, industrial quality control, and analysis of everyday materials. Thus, the project successfully demonstrates that refractive index serves as an effective tool for investigating the optical properties of common liquids and connects theoretical concepts of optics with real-life applications.

APPLICATIONS

Identification of substances – Refractive index helps in identifying different materials and liquids based on their optical properties.

Food industry – Used to check the purity and quality of edible oils, beverages, vinegar, and other food products.

Detection of adulteration – Helps in detecting impurities or dilution in liquids by comparing refractive index values with standard values.

Determination of concentration of solutions – Used to find the concentration of sugar solutions, salt solutions, and chemical solutions.

Chemical analysis – Helps in studying the composition and physical properties of substances in laboratories.

Medical applications – Used in optical instruments such as microscopes, diagnostic devices, and eyeglasses.

Industrial quality control – Used in industries to test the quality and purity of oils, chemicals, and pharmaceutical products.

Optical instrument design – Important in the design of lenses, cameras, telescopes, and spectrometers.

Fiber optic communication – Used in optical fibers for efficient transmission of light signals.

Scientific research – Helps in studying optical properties of materials and understanding light–matter interaction.

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