DETERMINATION OF REAL REFRACTIVE INDEX OF GLYCERIN SOLUTIONS USING PRISM SPECTROMETER

BY – ABDULKADIR ABDO ROBA

A Thesis Submitted To
The Department of Applied Physics
School of Applied Natural Sciences
Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Physics

Office of Graduate Studies
Adama Science and Technology University

Adama Ethiopia
August 2017

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DECLARATION

I hereby declare that this MSC/MA thesis is my original work and has not been presented for a degree any other university and all success of material used for this thesis have been dully acknowledged

Name: **Abdulkadir Abdo**
Signature________________

This Msc thesis has been submitted for examination with my approval as thesis advisor.
Name: **Alemu kebede (PhD)**
Signature________________

Date of submission: _______________

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY
GRADUATE STUDIES PROGRAM

This is to certify the thesis prepared by **Abdulkadir Abdo**; **Determination of Real Refractive Index of Glycerin Solutions Using Prism Spectrometer** and submitted in partial fulfillment of the requirement for the degree of Master of Science in physics complies with the regulations of the university meets the accepted standards with respect to originality and quality.

Signed by the examining committee

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Chairman,	**Signature**	**Date**
____________________	____________________	____________________
Advisor	**Signature**	**Date**
____________________	____________________	____________________
External Examiner	**Signature**	**Date**
____________________	____________________	____________________
Internal Examiner	**Signature**	**Date**

DEDICATION

This thesis is dedicated for my golden parent Mr. Abdo Roba and Mrs. koye Ali for they paid a grateful sacrifice for my education starting from the lower class up to the higher institution and also for my all brothers and sisters for there were initiating and supporting me for the success of my education. May almighty Allah bless them and give long life span with good healthy and wealthy.

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Above all, things I would like to thank almighty Allah, the Compassionate, the Most Merciful and Source of Knowledge & Wisdom who bestowed upon me the health, the power of communication and the audacity to accomplish this thesis.

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LIST OF ABBREVIATION AND ACRONYMS

USP ----------------------------- U.S pharmacopeia
PH.EUR------------------------ European pharmacopeia
EEC----------------------------- European economic community
CP------------------------------- chemically pure
BS------------------------------- British standard
ASTM-------------------------- American society for testing and materials

TABLE OF CONTENT

List of Figures

List of Tables

Abstract

In this research, the refractive index of glycerin solutions were determined using a prism spectrometer by measuring the angle of minimum deviation using laser light of different wavelengths. The solutions were prepared in volume fraction and the angles of minimum deviation for different standardized samples of glycerin solution were determined; the values of these angles were used to compute the refractive indices of samples by Snell's law. The value of calculated refractive index of the glycerin solutions for 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% 90% &100% concentrations were found to be in the range of 1.3210 to 1.4392, 1.3433 to 1.4598 and 1.3233- 1.4498 for extra zenith glycerin and 1.3321 to 1.4502, 1.3611 to 1.4719 and 1.3383- 1.4602 for clere glycerin using Red diode, Green diode and He-Ne lasers light respectively. The experimental result shows that the value of refractive index of glycerin solutions were Increases linearly as the concentration of glycerin increases, Decreases linearly as the temperature increases with negative slope and exponentially decreases as the wavelength of light increases.

Finally the real refractive index of extra zenith and clere glycerin were investigated and compared with refractive index reported by other researchers and they are in good agreement. In addition the refractive index of clere is more related to standard value of glycerin than that of the extra zenith.

Keywords: *Refractive Index, Concentration, Wavelength, and Temperature*

CHAPTER ONE

Introduction

The optical properties of a medium often manage the interaction of electromagnetic wave incident onto it. Thus, an electromagnetic wave starts interacting with the electrons in a medium, when the wave is allowed to propagate through it. The electric field associated with the wave causing them to vibrate and this forced oscillations of the electrons in the medium start radiating light by offering secondary sources of radiation. However, the speed of new waves changes according to the optical properties of the medium and it is always smaller than the speed of light in vacuum. All materials are characterized by their ability to slow down the waves, classified as optical refractive index [1].

Refractive index is one of the most important physical properties of solutions. By measuring the refractive index of a solution, one can determine the composition of the solution [2]. The refractive index of a substance describes an important part of its interaction with electromagnetic radiation. The refractive index is a basic optical property of materials and its accurate measurement is often needed in many branches of physics and chemistry and it has several applications to many industries and materials. It is measured for many reasons. It is clearly important to know the refractive index of materials used for their clarity, such as glasses and solid plastics. In complex fluids such as drinks or foods, the refractive index is a measure of dissolved or submicronic material [3, 4, 5].

There are numerous methods used for measuring the refractive index of a liquid solution that are well documented in text books [6], the most suitable and easiest method was reported [7, 8]. The diversity of methods is largely due to differences in applications, test objects and the required measurement accuracy. A separate class of devices for measuring the refractive index of transparent liquids consists of systems designed for examining liquids in cuvettes made of glass, quartz or other transparent materials. During the last decade, numerous practical devices based on the principle described above using various cuvettes have been constructed for determining the refractive index [9].

Glycerine is a material of outstanding utility with many areas of application. The key to glycerine's technical versatility is a unique combination of physical and chemical properties, ready compatibility with many other substances, and easy handling. Glycerine is also virtually nontoxic to human health and to the environment. The physical properties of glycerine is a water-soluble, clear, almost colorless, odorless, viscous, hygroscopic liquid with a high boiling point. The chemical properties of glycerine is a trihydric alcohol, capable of being reacted as an alcohol yet stable under most conditions. With such an uncommon blend of properties, glycerine finds application among a broad diversity of end uses. In some, glycerine is the material of choice because of its physical characteristics, while other uses rely on glycerine's chemical properties.

Glycerin is chemically a sugar alcohol . On the Nutrition Facts labels, it is included in total carbohydrates, and, as a subcategory, in sugar alcohols. There are many product types of glycerin which are presented in review literature in this thesis USP glycerin or pure glycerin, which is ordinary most of the people were used as cosmetics, is used as solution with pure water to calculate its refractive index.

Previously some researchers (authors) have reported that the use of an equilateral hollow prism would allow for the measurement of the refractive index of most ordinary liquids. It opens the possibility of studying small variations in the refractive index of a solution with concentration. So measurements of refractive index are widely used in many industrial and research applications to determine the concentration of solutions. However, refractive index at the same time also varies with temperature, pressure, and wavelength [10, 11].

Previous studies [12 -14] provide more detailed discussion on the concentration mapping by the measurement of refractive index of liquids. Temperature coefficient of refractive index can also be used to calculate thermal expansion coefficient [15].
This thesis reported a relatively simple and effective technique, which can be used to measure the refractive index of glycerin solutions at different concentration and different temperatures. We have utilized red diodes, green diodes and He-Ne lasers with wavelength of 650 nm, 532 nm and 632.8 nm respectively. Previously, hollow prism spectrometer method was used by other researchers to find the refractive index of sugar solution, Tinashe D. [16]. In this research the hollow prism spectrometer method was applied for measuring the real refractive index of glycerin solutions of extra zenith and clere under He-Ne laser, Red diode laser and Green diode

laser illumination and its value was compared with each other and to the reported measurements in the literature which are carried out using other method.

The thesis is organized as follows; in chapter one, the introductory part, the statement of problem, objectives of the study, significance of the study were presented. In Chapter two, the literatures related to glycerin and refractive index have been presented. The definition, origin and history of glycerin, terminology product type of glycerin, the physical and chemical properties of glycerin, and the applications of glycerin were presented as well as Snell's law, Angle of minimum deviation, Condition for minimum deviation, using a hollow prism to determine concentration of a solution and Description of refractive index using electron oscillator model were presented. In chapter three, the materials and methods used in this work as well as the procedures applied are presented. Preparation of glycerin solution at different level of concentrations were presented. In the same chapter, the techniques of the measurement are presented. The results and discussion of the thesis are presented in the fourth chapter. The calculated values of refractive index of glycerin solutions at different concentrations and at different temperatures are presented. The dependence of refractive index on the wavelength was presented. Finally, the thesis windup by conclusions and recommendations.

1.2. Statement of the problem.

Several methods have been employed to measure the real refractive index of glycerin solution and most of these methods have been expensive and may not always be available locally. Therefore, there was a need to obtain the real refractive index of glycerin solution, using hallow prism spectrometer, because the method is a simple and inexpensive method that can be used to measure the real refractive index of glycerin solution. So, in this research the researcher was used an equilateral hollow prism which locally constructed from inexpensive and easily found materials to determine the refractive index of glycerin solution of Ethiopia(zenith) and south Africa(clere) by applying Snell's law. As far as our knowledge is concerned, there is no research report to determine the refractive index of glycerin solution in Ethiopia using laser induced prism.

Therefore, based on the above investigation the study aim to determine the real refractive index of glycerin solutions of extra zenith and clere using prism spectrometer.

1.3. Objectives of the Research

1.3.1. General Objective:

The general objective of this thesis is to determine real refractive index of Glycerin solutions by using prism spectrometer to insure the quality of light pure glycerin (cosmetics which is used for skin).

1.3.2.Specific Objectives:

The specific objective of this thesis are

- To identify the effect of concentration, on the refractive index of glycerin solution.
- To evaluate the effect of temperature, on the refractive index of glycerin solution.
- To assess the effect of wavelength of laser light on the refractive index of glycerin solution.
- To compare the value of refractive index of glycerin solutions of different types using red diode, green diode and He-Ne lasers.

1.4. Significance of the Research

As mentioned above the general objective of the study is to determine refractive index of Glycerin solution by using prism spectrometer to ensure the quality of light glycerin. Therefore this study expected to be helpful for the following:-

- It helps to approve the quality of pure glycerin (cosmetics) for the daily user.
- The factory might maximize the quality of its product and have more costumers.
- Due to the quality of the product, it will be competitive in the world market and this may reduce the foreign currency with those kinds of cosmetics' were imported to our country.

Finally, this study may also helpful for those who like to study similar research as a reference.

CHAPTER TWO

Literature Review

In this chapter, the literatures related to glycerin and refractive index have been presented. The definition, origin and history of glycerin, terminology product type of glycerin, the physical and chemical properties of glycerin, and the applications of glycerin were presented as well as Snell's law, Angle of minimum deviation, Condition for minimum deviation, using a hollow prism to determine concentration of a solution and Description of refractive index using electron oscillator model were presented.

2.1. Glycerin

2.1.1. Definition, Origin and History of Glycerin

Glycerin is chemically a sugar alcohol . On the Nutrition Facts labels, it is included in total carbohydrates, and, as a subcategory, in sugar alcohols. Glycerin, glycerine and glycerol are 3 names for the same substance. The name glycerin or glycerine is usually used as a product name and the name glycerol for the ingredient, for example, glycerin syrup contains 99.7 glycerol. The chemical formula of glycerin (glycerol) is $C_3H_5\,(OH)_3$.

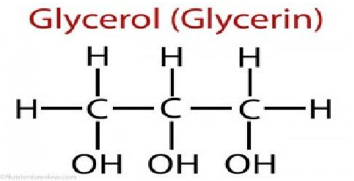

Figure: 2.1 the chemical formula of glycerin (glycerol) [17]

The origin, chemical structure, and utility of glycerine have been known for little more than two centuries. Glycerine was accidentally discovered in 1779 by K. W. Scheele, the Swedish chemist, while he was heating a mixture of olive oil and litharge (lead monoxide). Scheele called glycerine the "sweet principle of fat." Scheele later established that other metals and glycerides produce the same chemical reaction which yields glycerine and soap and, in 1783, he published a description of his method of preparation in transactions of the Royal Academy of Sweden. Scheele's method was used to produce glycerine commercially for some years [17].

The immense potential of glycerine went largely untapped until M. E. Chevreul, the French pioneer investigator of fats and oils, studied it early in the 19th Century. Chevreul named Scheele's "sweet principle of fat" glycerine in 1811 after the Greek word, glykys, meaning sweet." In 1823 Chevreul obtained the first patent for a new way to produce fatty acids from fats treated with an alkali, which included the recovery of glycerine released during the process. Thirteen years later, Pelouze, another French investigator, announced the empirical formula as $C_3H_80_3$. The accepted structural formula, $C_3H_5(OH)_3$ was established by Berthelot and Lucea almost fifty years later in 1883. Glycerine did not become economically or industrially significant until Alfred Nobel invented dynamite in 1866 after twenty years of experimentation. Nobel's invention successfully stabilized trinitroglycerin, a highly explosive compound, by absorption on kieselguhr, which permitted safe handling and transportation [17].

The invention of dynamite and the later invention of blasting gelatin, also by Nobel, thrust glycerine into economic and military importance. Dynamite became the first worldwide technical application for glycerine and through it, glycerine had an enormous influence on industrial development. Dynamite unlocked immense underground deposits of minerals and fuels from which much chemical and technical progress later sprang. Huge amounts of dyhamite were also consumed in building railroads and in other construction projects. A notable example is the Panama Canal, which required about 8,000 tons of the explosive, an amount equivalent to about 4,000 tons of glycerine.

2.1.2. Terminology product types of glycerine

Glycerine is an important article of domestic and international commerce. The designations for the various grades of glycerine used in the United States and in Europe are prevalent worldwide because these areas are the leaders in glycerine production and consumption. Accordingly, reference is made to European nomenclature for similar U.S. grades or types of commercially available glycerine where possible in the discussion that follows.

USP glycerin is a clear, almost colorless product for uses requiring glycerine of high purity with taste and odor characteristics desirable for pharmaceutical and food purposes. Its glycerol content in aqueous solution is "not less than 95%," as defined by a specific gravity of not less than 1.249 at 25/25°C. The designation USP is an abbreviation of U.S. Pharmacopeia and signifies that the glycerine thus designated meets or exceeds the standards established in U.S. Pharmacopeia (USP XXII, 1990) monograph, Glycerin. The USP designation has official legal status in the United States since the U.S. Pharmacopeia has been incorporated by reference in various statutes and regulations governing drug and medical practices, of which the federal Food, Drug, and Cosmetic Act is the most significant. USP glycerine is commonly available commercially at anhydrous glycerol content levels of 96%. 99.0% and 99.5%. Concentrations above 99.5% are also available commercially. The European equivalent of USP in the United States is PH.EUR. Commonly followed by a percentage indicating glycerol content (e.g., PH.EUR.99.5%). The PH.EUR label signify that the glycerine so designated meets the specifications of the European Pharmacopoeia 11(1986), as determined by analytical methods given in the same compendium. The European Pharmacopeia obtains in the European Economic Community (EEC), i.e., it supersedes the national pharmacopeias of member countries.

CP glycerine or chemically pure glycerine is generally understood to be of the same quality or grade as USP glycerine, but this term is considered generic in the United States because it does not reflect compliance with any official quality requirements or specifications as does the USP designation. In Europe, the term CP glycerine is understood to conform the standard specification for chemically pure glycerol, BS 2625:1979 issued by the British Standards Institution. A notation in this standard states that glycerol meeting the criteria of BS 2625:1979 will also comply with the requirements of the European Pharmacopeia.

Food grade glycerine in the United States meets the requirements outlined in the monograph glycerin contained in the Food Chemicals Codex prepared by the Committee on Food Protection of the National Research Council. Food grade requirements are similar to USP standards. Within the European Economic Community, glycerine for use in food products must comply with Council Directive 78/663/EEC which specifies the standards of purity for emulsifiers, stabilizers, thickeners, and gelling agents for use in foods.

High gravity glycerine is a designation used in the United States for a commercial grade of glycerine that is clear, almost colorless and conforms to Federal Specification 0-G-491C issued November 14, 1983 by the General Services Administration. This product also conforms to Standard Specification for High-Gravity Glycerin, 0-1257, issued by the American Society for testing and Materials (ASTM). This grade must contain not less than 98.7% glycerol based on specific gravity of 1.2587 minimum at 25/25^{o}c.

It is commonly supplied at not less than 99.0% concentration (specific gravity minimum 1.2595 at 25/25^{o}c). ASTM Standard Specification D-1257 is also recognized in Europe to define a grade of glycerine for industrial purposes.

Dynamite glycerine in the United States meets all the High Gravity grade specifications except color, but it cannot be darker than the Federal Color Standard. In Europe, glycerine for use in explosives is defined by Specification 21D for dynamite glycerine issued by the Nobel Explosives Company Ltd. The British Standards Institution has also issued standard specification for this grade of glycerine as British Standard Specification for Dynamite Glycerol, BS 2624: 1979.

Saponification (88%c) rude and soap lye (80%c) rude are generic terms used in the United States to designate grades of crude glycerine recovered from triglycerides. The percentages refer to the glycerol content of the crudes. Saponification crude is a concentrate of the "Sweetwater" from fat hydrolysis or "splitting." In Europe, the term for this type of crude is hydrolyser crude glycerol. Hydrolyser crude glycerol contains not less than 88% glycerol and conforms to British Standard Specification BS 2622: 1979. Soap lye crude is the product of the spent lye of the soap kettle, after concentration in a desalting evaporator. In Europe, crude glycerine of this derivation is called soap lye crude glycerol. It contains not less than 80.0% glycerol and meets the requirements given in British Standard Specification for Soap Lye Crude Glycerol BS 2621:1979. Although important articles of commerce. These grades of glycerine are almost never consumed in any process except refining.

2.1.3. Properties of glycerin

2.1.3.1. Physical Properties

It is a clear, almost colorless, viscous, high-boiling liquid miscible with water and alcohol, and like these materials, a good solvent. At low temperatures, glycerine tends to supercool, rather than crystallize. Water solutions of glycerine resist freezing, a property responsible for glycerine's use as a permanent antifreeze in cooling systems. Among its most valuable attributes are hygroscopicity, or the ability to absorb moisture from the atmosphere, and low vapor pressure, a combination that produces outstanding permanent humectancy and plasticity. Glycerine is virtually nontoxic in the digestive system and non-irritating to the skin and sensitive membranes, except in very high concentrations when a dehydrating effect is noted. It is also odorless and has a warm sweet taste.

Specific Gravity:

Measurement of specific gravity is the principal means of determining the glycerol content of distilled glycerine. In 1927, Bosart and Snoddyc published their determination of the specific gravity of glycerol solutions, as measured under carefully controlled conditions at 15/ 15, 15.51-15.5, 20/20 and 25/25 $\pm 0.1^{0}$C[18]. The specific gravity of glycerin in air is 1.2636 at 20°C and 1.2620 at 25°C.

Density:

The density of glycerol solutions at various concentrations and temperatures was calculated from their specific gravity. The density of glycerin at 20°C was 1.26134 gm/ml.

Boiling Point:

The boiling point of pure glycerol at atmospheric pressure (760 mm) is 290^{0}C based on determinations by a number of investigators [19].

Vapor Pressure:

Glycerol has a lower vapor pressure than would be expected from its molecular weight, as a result of the molecular association characteristic of alcohols. Many of the important uses of glycerine are dependent on its relative non-volatility. Consequently, there have been a number of determinations of its vapor pressure and its partial pressure in glycerol solutions and its Vapor Pressure 0.0025 mm (50°C) [20].

Hygroscopicity:

Anhydrous glycerol has a very high affinity for water, a property responsible for its uses as a drying agent for gases, for the preparation of anhydrous alcohol, etc. The ability to attract moisture from the air and hold it is one of the most valuable properties of glycerol. It is the basis for its use as a humectant, and also for its use as a conditioning agent where both the glycerol itself and the water it holds act as plasticizers. Glycerol solutions, at any concentration, will gain or supply moisture until a concentration is reached which is in equilibrium with the moisture of the air.

Viscosity:

Many measurements of the viscosity of glycerol and glycerol solutions have been made, using different types of viscometers. The Viscosity of glycerin was 1499 centipoises (20°C) [21].

Freezing Point:

The freezing point of pure glycerol has been variously reported at values distributed closely around 18.17^{O}C as perhaps the most precise. Glycerol is seldom seen in its crystallized state, because of its tendency to supercool, and the pronounced effect of small amounts of water in depressing the freezing point.

Specific Heat:

The specific heat of pure glycerol has been determined by several investigators with values in the range of 0.575 to 0.5795 Cal per gm at 26^{0}c [22&23]. The specific heat of glycerol-water mixtures is higher. Because of its refrigerant properties, the heat capacity of glycerol and glycerol solutions have been thoroughly explored at low temperatures.

Refractive Index:

The refractive index of 100% glycerol was 1.47399 at 20^{o}c. Being easily measured and sensitive to dilution with water it may be used as a measure of concentration [24].

Solubility and Solvent Power:

Because of its hydroxyl groups glycerol has solubility characteristics similar to those of water and the simple aliphatic alcohols. It is completely miscible with water, methyl alcohol, ethyl alcohol, n-propyl alcohol, isopropyl alcohol, n-butyl alcohol, isobutyl alcohol, sec.-butyl alcohol, tertiary amyl alcohol, ethylene glycol, propylene glycol, trim ethylene glycol and phenol. It is soluble to the extent of 5% by weight in acetone at ordinary temperatures. Nine parts of glycerol are soluble in 100 parts of ethyl acetate. It also has limited solubility in dioxide, and ethyl ether. It is practically insoluble in higher alcohols, in fatty oils and the hydrocarbons and chlorinated solvents such as chlorhexane, chlorobenzene and chloroform. It is completely miscible with ethylene glycol monoethyl ether but is miscible with only a limited amount of ethylene glycol monobutyl ether.

Compressibility:

Glycerol is one of the least compressible of liquids, being only one half as compressible as water and having a compressibility of 21.10 x 10^{-6} cc per atm per cm^2 at 28.5°C [25].

2.1.3.2. Chemical Properties

Glycerine is a trihydric alcohol and, like other alcohols, forms esters, ethers, amines, aldehydes, and compounds analogous to metallic alcoholates. But, because of its multiple hydroxyl groups, it can be reacted to form an unusually large number of derivatives. One, two or three of these hydroxyls can be replaced with other chemical groups, thus permitting the synthesis of many different derivatives with properties designed for specific applications. Structurally, glycerine has two primary and one secondary hydroxyl groups.

The primary hydroxyl groups generally are more reactive than the secondary group and, of the two primary groups, the first to react usually does so more readily than the second. In any reaction, however, the second and third hydroxyls will react to some extent before all the most reactive groups are exhausted. Reaction mixtures thus contain isomers and products of different degrees of reaction, with the relative amounts of each reflecting their ease of formation.

Glycerine is stable to atmospheric oxidation under ordinary conditions, but can be readily oxidized by other oxidants. Partial oxidation is generally difficult to control to give a large yield of a single product.

2.1.4. Applications of Glycerin

Food and Beverages

In foods and beverages, glycerine functions as a humectant, solvent, sweetener, and preservative. It acts as a solvent for flavors and food colors in soft drinks and confections and as a humectant and softening agent in candy, cakes, and casings for meats and cheese. Glycerine is also used in dry pet foods to help retain moisture and enhance palatability.

Drugs

Glycerine is one of the most widely used ingredients in drugs and pharmaceuticals. It functions as a solvent, moistener, humectant, and bodying agent in tinctures, elixirs, ointments, and Capsules for medicinal use, which are plasticized with glycerine, are another important application. Other well-known uses include suppositories, ear infection remedies, anesthetics, cough remedies, lozenges, gargles, and vehicles for antibiotics and antiseptics.

In veterinary medicine, glycerine has been used as a source of glucose in bovine ketosis and nitroglycerine as a treatment for bronchial asthma in dogs [26].

3. Cosmetics and Toiletries

Glycerine is widely used in cosmetics and other toiletry applications, being virtually nontoxic, non-irritating, and odorless. It functions as a humectant, vehicle and emollient. Glycerine is a major toothpaste ingredient, preventing drying out and hardening in the tube and around the cap threads or at the opening of the pump type dispenser. Other uses include skin creams and lotions, shaving preparations. Deodorants, and make up. Glycerol esters of fatty acids, an important class of glycerine derivatives, are utilized as emulsifiers in creams and lotions and as replacements for waxes in lipstick, in mascara, and in other non-greasy emulsions

Tobacco

A glycerine content of about 3% keeps tobacco moist and soft to prevent breaking and crumbling during processing and to ensure freshness in packaged cigarettes and other tobacco products. Sheet-formed cigar tobacco is plasticized with glycerine. It also adds flavor to chewing and pipe tobaccos. Nia cetin (glycerol triacetate) acts as a plasticizer for cellulose acetate in the manufacture of cigarette filter-tips.

Surface Coating Resins

Alkyds are an important class of resins used in surface coatings. Glycerine, because of its chemical versatility and process advantages, is a standard component in the manufacture of these resins. Alkyd resins produced from glycerine may readily be modified to meet a wide range of coating applications and demanding conditions.

Paper and Printing

Glycerine is used in the manufacture of papers as a plasticizer/humectant and lubricant. In addition to the softening effect of retained moisture, it also reduces shrinkage. It is likewise useful with other ingredients in specialty treatments such as grease-proofing. Since many papers are used as food wrappers or in sanitary products, glycerine's essential nontoxicity, freedom from odor, and stability meet other important quality requirements. Glycerine also finds extensive use in ink manufacture, especially the alkyd resins which are an important constituent of many printing inks.

Lubrication

Glycerine plays an important role in the lubricants used in many applications because of its stability over a broad range of temperatures and pressures. In addition, the virtually nontoxic character of glycerine makes it suitable for lubrication of food and other machinery where product purity is of paramount importance. Glycerine is a textile conditioning agent used widely in lubricating, sizing, and softening yarn and fabric. Its effectiveness in these and similar applications is due mainly to its viscosity and hygroscopicity. Glycerine is also successfully used to lubricate many kinds of fibers in spinning, twist setting, knitting, and weaving operations.

Rubber and Plastics

Glycerine's main use in the rubber industry is for its lubricating action on rubber. In the plastics industry, glycerine is used as a plasticizer and lubricant.

Urethane Polymers

In this application, glycerine serves as the fundamental building block in polyether for urethane foams. The flexible foams resulting from the processes utilizing glycerine have superior properties with respect to humid aging and resilience. Glycerine-based polyether have also found some application in rigid foams and particularly, in urethane coatings.

Electrical and Electronics

Glycerine is widely employed for the manufacture of electrolytes for electrolytic condensers used in radios and neon lights and in processes for electrodeposition and treatment of metals. Electronic applications are mostly of a proprietary nature. Although one use in this field is associated with the production of computers.

Nitration

The nitration of glycerol to yield nitroglycerine is probably the most well-known application. Dynamite, as it is manufactured today, is a mixture based on an explosive compound, usually nitroglycerine, mixed with an absorbent, usually diatomaceous earth, in a proportion of about 3:1 nitroglycerine to the absorbent. Nitroglycerine is also used as a cardiovascular agent, functioning as a vasodilator in coronary spasm and as an antianginal agent [27]. It has also been used therapeutically for canine bronchial asthma [27].

2.2. Description of refractive index using Snell's law

Snell's law (also known as Descartes' law or the law of refraction), a formula used to describe the relationship between the angles of incidence and refraction, for light or electromagnetic waves, passing through a boundary between two different transparent medias, such as air and glass or others. Snell's law states that the ratio of the Sine of the angles of incidence to the Sine of the angle of refraction is a constant that depends on the properties of the media [28]. When a light ray incident on an interface point of the two medias with different refractive indices at an angle of incident θ which is the angle between the ray of incident and the normal line which is perpendicular to the surface, it becomes refract either towards or away from the normal depending on the optical density of the two medias at an angle of refraction θ which is the angle formed between ray of refracted and the normal line as shown in figure 2.2

Suppose a light ray is incident on an interface separating two transparent media. The incident ray is then partially reflected to the first medium and partially transmitted (reflected) to the second medium.

The refractive ray makes an angle θ_r with the normal ray and the incident ray makes an angle with the normal. If n_1 is the refractive index of the first medium and n_2 is that of the second medium, then Snell's law states that: $\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_2}{n_1}$. Moreover, if v_1 is speed of light in the first medium and v_2 is speed in the second medium, the Snell's law is expressed as: $\frac{\sin\theta_i}{\sin\theta_r} = \frac{v_1}{v_2}$,

Where θ_i is incident angle and θ_r is angle of refraction.

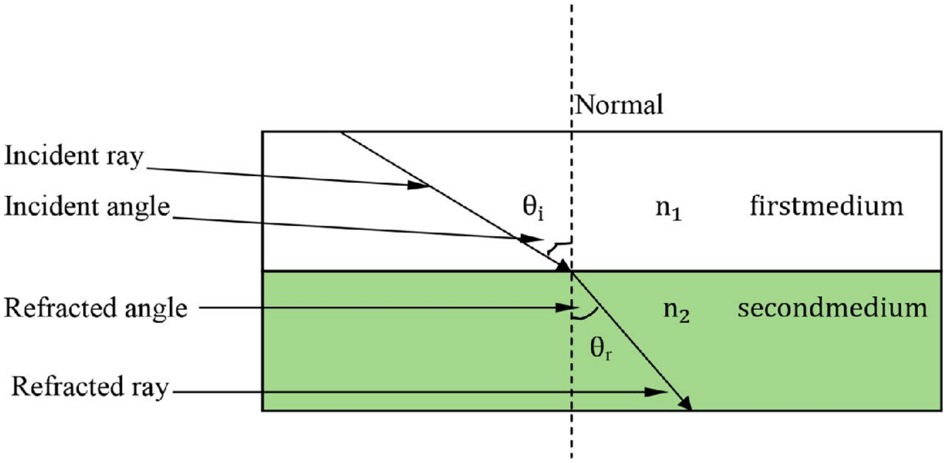

Figure: 2.2. Graphic of Snell's law

Mathematically Snell's law also can be rewired as;

$$n_1 sin\theta_i = n_2 sin\theta_r \tag{2.1}$$

$$\frac{sin\theta_i}{sin\theta_r} = \frac{n_2}{n_1} = constant\ (n) \tag{2.2}$$

Where: θ_i and θ_r are angle of incidence and angle of refraction respectively.

n_1 and n_2 are the refractive indices of the first and second medium respectively, and

$n = \frac{n_2}{n_1}$ is the relative refractive index (i.e. relative to the refractive index of vacuum)

As light passes the border between the two media, depending upon the relative refractive indices of the two media, the light will either be refracted to a lesser angle, or a greater one. These angles are measured with respect to the normal line, a line perpendicular to the boundary at the point of incidence. Snell's law is used to determine the direction of light rays through refractive media with varying indices of refraction. The indices of refraction of the media, labeled n_1 and n_2, are used to represent the factor by which light is "slowed down" within a refractive medium, such as glass or water, compared to its velocity in a vacuum.

2.2.1. Angle of minimum deviation

Angle of deviation is the angle through which an incident ray deviates. By measuring the angle of deviation from various angles of incident, we can determine the angle of minimum deviation and refractive index of the prism.

Figure 2.3.shows the set up to determine the angle of minimum deviation using a prism.

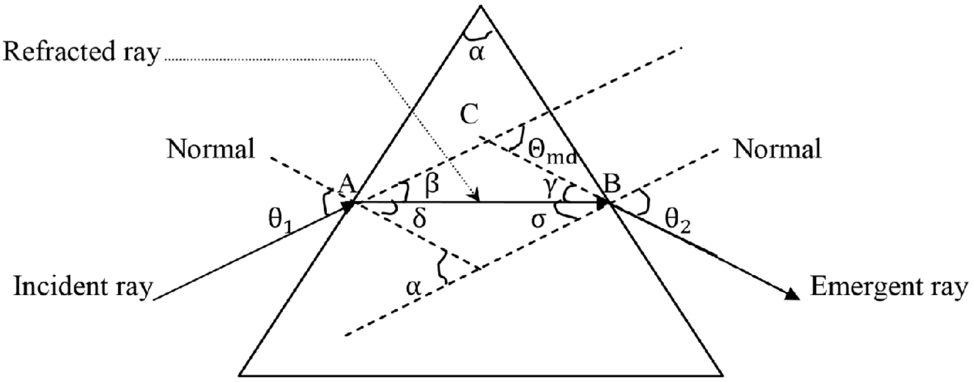

Figure: 2. 3. The geometry of a light rays passing through a prism. Where: α is the apex angle, θ_1 and δ are the angles of incidence and angle of refraction on surface A respectively, and σ and θ_2 are the angle of incidence and angle of refraction on surface B respectively. θ_{md} is the angle of minimum deviation. If a light of ray is incident on the first surface of the prism at an angle of θ_1 then the refraction at both surfaces obeys Snell's law [29]. then due to the refraction at surface A, we can write Snell's law as:

$$\frac{sin\theta_1}{sin\delta} = \frac{n_g}{n_a} \tag{2.3}$$

Where: n_g and n_a are refractive indices of the glass and air respectively. Application of Snell's law at point B yields:

$$\frac{Sin\sigma}{sin\theta_1} = \frac{n_a}{n_g} \tag{2.4}$$

or

$$\frac{sin\theta_2}{sin\sigma} = \frac{n_g}{n_a} \tag{2.5}$$

Equates equation (2.3) and (2.5) yields:

$$\frac{sin\theta_1}{sin\delta} = \frac{n_g}{n_a} = \frac{sin\theta_2}{sin\sigma} \qquad (2.6)$$

The angle of deviation produced by the first surface is:

$$\beta = \theta_1 - \delta \qquad (2.7)$$

and the angle of deviation produced by the second surface is:

$$\gamma = \theta_2 - \sigma \qquad (2.8)$$

The total angle of minimum deviation is thus:

$$\theta_{md} = \beta + \gamma \qquad (2.9)$$

Now substitute equation 2.7 and 2.8 into 2.9 and it yields:

$$\theta_{md} = \theta_1 + \theta_2 - (\delta + \sigma) \qquad (2.10)$$

But, $\delta + \sigma = \alpha$

Therefore, equation (2.10) becomes: -

$$\theta_{md} = \theta_1 + \theta_2 - \alpha \qquad (2.11)$$

2.2.2. Condition for minimum deviation

The angle of minimum deviation occurs at a particular angle of incidence where the refracted ray inside the prism makes equal angles with the two prism faces. This occur when the path of the light inside the prism is parallel to the base of the prism. Therefore, it means that figure 2.3

$$\theta_1 = \theta_2, \qquad \beta = \gamma, \qquad \delta = \sigma$$

On account of equation (2.11) we can thus write the minimum angle of deviation as:

$$\theta_{md} = 2\,\theta_1 - \alpha \qquad \text{or} \qquad \Theta_{md} = 2\,\theta_2 - \alpha \tag{2.12}$$

This implies that: And from equation (2.10) it follows that:

$$\theta_1 = \frac{1}{2}(\theta_{md} + \alpha) \text{ or } \theta_2 = \frac{1}{2}(\theta_{md} + \alpha) \tag{2.13}$$

$$\sigma = \frac{1}{2}\,\alpha \, or \, \delta = \frac{1}{2}\,\alpha \tag{2.14}$$

2.2.3. Determining refractive index of a solution using a hollow prism Spectrometer

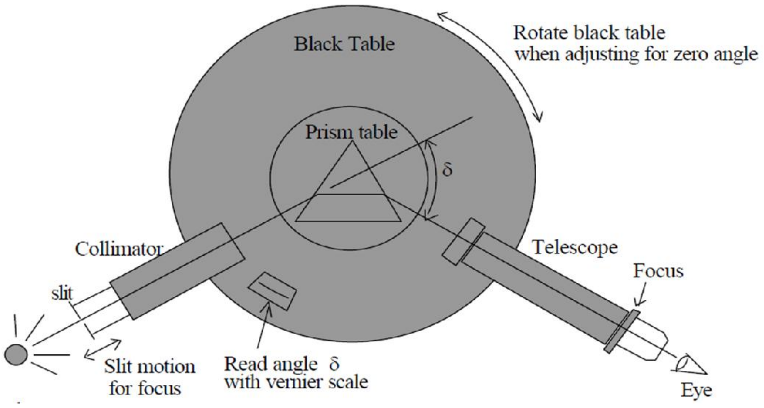

Figure: 2.4. Prism spectrometer

The spectrometer is an instrument for analyzing the spectra of radiations. The hollow-prism spectrometer is suitable for measuring ray deviations and refractive indices. Sometimes a diffraction grating is used in place of the prism for studying optical spectra. A prism refracts the light into a single spectrum, whereas the diffraction grating divides the available light into several spectra. Because of this, slit images formed using a prism are generally brighter than those formed using a grating. Spectral lines that are too dim to be seen with a grating can often be seen using a prism. Unfortunately, the increased brightness of the spectral lines is offset by a decreased resolution, since the prism doesn’t separate the different lines as effectively as the grating. However, the brighter lines allow a narrow slit width to be used, which partially compensates for the reduced resolution.

With a prism, the angle of refraction is not directly proportional to the wave length of the light. Therefore, to measure wavelengths using a prism, a calibration graph of the angle of deviation versus wavelength must be constructed using a light source with a known spectrum. The wavelength of unknown spectral lines can then be interpolated from the graph. Once a calibration graph is created for the prism, future wavelength determinations are valid only if they are made with the prism aligned precisely as it was when the graph was produced. To ensure that this alignment can be reproduced, all measurements are made with the prism aligned so that the light is refracted at the angle of minimum deviation.

The light to be examined is rendered parallel by a collimator consisting of a tube with a slit of adjustable width at one end and a convex lens at the other. The collimator has to be focused by adjusting the position of the slit until it is at the focal point of the lens. The parallel beam of light from the collimator passes through a glass prism standing on a prism-table which can be rotated, raised or lowered, and leveled. The prism deviates the component colors of the emitted light by different amounts and the spectrum so produced is examined by means of a telescope, which is mounted on a rotating arm and moves over a divided angular scale.

The theory of the prism spectrometer indicates that a spectrum of maximum definition is obtained when the angular deviation of a light ray passing through the prism is a minimum. Under such conditions it can be shown that the ray passes through the prism symmetrically. For a given wavelength of light traversing a given prism, there is a characteristic angle of incidence for which the angle of deviation is a minimum. This angle depends only on the index of refraction of the prism and the angle between the two sides of the prism traversed by the light. The relationship between these variables is given by the equation:

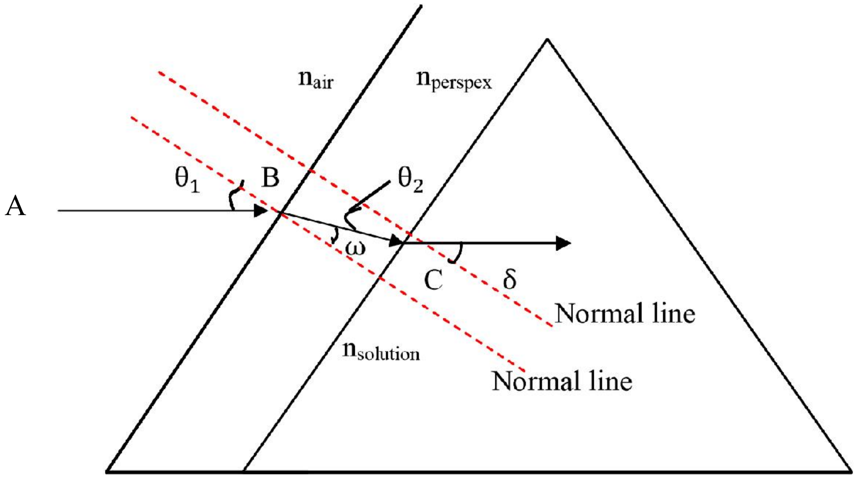

Figure: 2.4. The geometry of a light ray passing through a hollow prism

From A to B, light is travelling in air. It is refracted at B and travels in the Perspex up to C. At C it is refracted again and we assume it travels parallel to the base of the prism to achieve minimum deviation. By applying Snell's law at B:

$$n_{air} sin\theta_1 = n_{per}\ \mathrm{sin}\omega \tag{2.15}$$

Where: n_{air} and n_{per} are the refractive indices of air and Perspex respectively. The only unknown parameter in equation (2.15) is the angle of refraction, ω. It can be obtained by rearranging Equation (2.15)

$$\mathrm{sin}\omega = \frac{n_{air} sin\theta_1}{n_{per}} \tag{2.16}$$

Again by applying Snell's law at C,

$$n_{per}\ sin\theta_2 = n_{sol}\ \mathrm{sin}\ \delta \tag{2.17}$$

Were n_{sol} – refractive index of solution. Because of $\theta_2 = \omega$, we see that

$$n_{per}\ \mathrm{sin}\omega = n_{sol}\ \mathrm{sin}\ \delta$$

or

$$\sin\omega = \frac{n_{sol}\sin\delta}{n_{per}} \tag{2.18}$$

Now, equates equation (2.16) and (2.18), we note that:

$$\frac{n_{air}sin\theta_1}{n_{per}} = \frac{n_{sol}\sin\delta}{n_{per}}$$

Or

$$n_{air}sin\theta_1 = n_{sol}\sin\delta \tag{2.19}$$

Now substitution of equation (2.14) into (2.19) leads to:

$$\mathrm{n_{air}Sin}\,\frac{1}{2}\,(\alpha + \Theta_{\mathrm{md}}) = \mathrm{n_{sol}sin}\frac{1}{2}\,(\alpha) \tag{2.20}$$

Since the refractive index of the air is 1, the refractive index of the solution can be written as:

$$\mathrm{n_{sol}} = \frac{\mathrm{n_{air}sin}(\frac{1}{2}\,(\alpha + \Theta_{\mathrm{md}}))}{\sin(\frac{1}{2}(\alpha))} \tag{2.21}$$

For this research the angle of apex α=60^0. Therefore, equation (2.21) becomes:

$$\mathrm{n_{sol}} = \frac{\sin(\frac{1}{2}\left(60^0 + \Theta_{\mathrm{md}}\right)}{\sin(30^0)} \tag{2.22}$$

It then follows that:

$$n_{sol} = 2\sin\left(\frac{1}{2}\Theta_{md} + 30^0\right) \qquad (2.23)$$

Where: Θ_{md} is determined experimentally using a prism spectrometer.

2.3. Description of refractive index using electron oscillator model

From classical electron oscillator model the Lorenz force is given by [30]

$$\mathbf{F} = e(\mathbf{E} + \mathbf{VxB}) \qquad (2.24)$$

Where: F is Lorentz force, v is velocity, e is electron charge, E is electric field and B is magnetic field.

We assume that equation (2.24) applies to the individual protons and electrons in atoms. Although these particles and their interactions can be properly treated only using quantum theory, their interaction with light can be treated very accurately in most cases with classical laws and concepts.

The electron has mass m_e and charge e and nucleus has mass m_n and charge +e. The nucleus exerts a binding force F_{en} on the electron, depending on the relative separation $r_{en} = r_e - r_n$. The electron also exerts a force F_{ne} on the nucleus, and according to Newton's third law,

$$F_{en}(r_{en}) = -F_{ne}(r_{en}) \qquad (2.25)$$

The Newton equations of motion for the electron is therefore

$$m\frac{d^2x}{dt^2} = e\,E(R,t) + F_{en}(x) \qquad (2.26)$$

Assume R as position of nucleus and m = mass of electron

In the absence of external force, the atom has a certain equilibrium position. Under the influence of an electromagnetic field, the electron experiences the Lorentz force (2.24) and is displaced from its equilibrium position; according to Lorentz "the displacement will immediately give rise to a new force by which the particle is pulled back towards its original position, and which we may therefore appropriately distinguish by the name of elastic force" [31]. Lorentz's assertion is equivalent to the replacement $F_{en}(x)$ by $-k_sx$, where: k_s is the "spring constant" associated with the hypothetical elastic force. This leads to the equation

$$\left.\begin{aligned} m\frac{d^2x}{dt^2} &= e\,E(R,t) - k_s x \\ \left(\frac{d^2}{dt^2}+\omega_0^2\right)x &= \frac{eE}{m}(R,t) \end{aligned}\right\} \tag{2.27}$$

Where: $\omega_0 = \sqrt{\frac{k_s}{m}}$ is the electron's natural frequency of oscillator

If we take a frictional force for granted and explore its consequences, we simply amend the Newton force law (2.27) to be written as:

$$m\frac{d^2x}{dt^2} = e\,E(R,t) - k_s x + F_{fric} \tag{2.28}$$

This frictional (drag) force can be given as:

$$F_{fric} = -bv = -b\frac{dx}{dt} \tag{2.29}$$

For an electron oscillator in a linearly polarized monochromatic plane wave equation (2.28) takes the form [30]:

$$\frac{d^2x}{dt^2} + 2\beta\frac{dx}{dt} + \omega_0^2 x = \hat{\epsilon}\frac{e}{m}E_0\cos(wt-kz) \tag{2.30}$$

Where: $\beta = \frac{b}{2m}$, the unit vector $\hat{\epsilon}$ defines the polarization of the applied field. then equation (2.30) for the electron oscillator with frictional damping is most easily solved by first writing it in complex form as

$$\frac{d^2x}{dt^2} + 2\beta\frac{dx}{dt} + \omega_0^2 x = \hat{\epsilon}\frac{e}{m}E_0\,e^{i(\omega t-kz)} \tag{2.31}$$

Where: we follow the convention of writing: $E_0\,cos(wt-kz)$ as $E_0\,e^{i(\omega t-kz)}$

and $E_0\,cos(wt-kz)$ is real part of $E_0\,e^{i(\omega t-kz)}$

This means that x (t) in (2.31) is also regarded mathematically as a complex quantity in our calculations, but only its real part is physically meaningful. In other words, we may submit the process of taking the real part of (2.61) until after our calculations, at which point the real part of our solution for x (t) is the (real) electron displacement. This approach is used frequently in solving linear equations such as (2.30). We solve (2.31) by writing;

$$\mathrm{X}\,(\mathrm{t}) = \mathrm{a}e^{-\mathrm{i}(\omega \mathrm{t}-\mathrm{kz})} \tag{2.32}$$

And after inserting this into equation 2.31 we obtain

$$(-\omega^2 - 2\,\beta i\omega + \omega_0^2\,)\mathrm{a} = \hat{\in}\,\frac{\mathrm{e}}{m}\,\mathrm{E}_0 \tag{2.33}$$

Therefore, the assumed solution (2.32) satisfy equation (2.31)

$$\mathrm{a} = \frac{-\hat{\in}\,\frac{\mathrm{e}}{m}\,\mathrm{E}_0}{(\omega 2\,-\,2\beta \mathrm{i}\omega+\omega_0^2\,)} \tag{2.34}$$

In view of equation (2.32) and (2.34) the physically relevant solution is expressed as

$$\mathrm{x}\,(\mathrm{t}) = Re\Big[\frac{-\widehat{\in(}\,\frac{\mathrm{e}}{m}\,)\mathrm{E}_0 e^{-i(\omega t-kz)}}{(\omega_0^2-\omega 2\,-\,2\beta \mathrm{i}\omega)}\Big] \tag{2.35}$$

From equation (2.35) for classical oscillator, the electron displacement due to an applied electric field $\hat{\in}$ $\mathrm{E}_0 cos(wt - kz)$ is given as: [30]

$$\mathrm{x(t)} =\hat{\in}\,\frac{\mathrm{e}}{m}\,\mathrm{E}_0\Big[\frac{\omega_0^2-\omega 2}{(\omega_0^2-\omega 2)^2+4\beta^2\omega^2)}\cos(\mathrm{wt}-\mathrm{kz})+\frac{2\beta \mathrm{i}\omega}{(\omega_0^2-\omega^2)^2+4\beta^2\omega^2)}\,sin(\mathrm{wt}-\mathrm{kz})\Big] \tag{2.36}$$

The first term in brackets is in phase with the electric field, whereas the second term is “in quadrature,” that is, its phase differs is by $\frac{\pi}{2}$ from that of the field. The in-quadrature part of the induced electric dipole moment d = ex is responsible for absorption (or stimulated emission) of light. The in-phase part of the induced dipole moment is responsible for the refractive index. According to basic electromagnetic theory the refractive index at frequency ω of a medium of N atoms per unit volume is given by the formula $\mathrm{n}^2(\omega) = 1 + \frac{\mathrm{N}\alpha(\omega)}{\varepsilon_o}$ where the polarizability α(ω) is defined by writing the in-phase component of d as $\alpha\hat{\varepsilon}E_0$(cos (ωt − kz). Thus, from Eq. (2.36),

$$\alpha(\omega) = \frac{e^2}{m}\left[\frac{\omega_0^2-\omega^2}{\omega_0^2-\omega^2)^2+4\beta^2\omega^2}\right] \qquad (2.37)$$

and

$$n^2(\omega) - 1 = \frac{Ne^2}{\epsilon_o m}\left[\frac{\omega_0^2-\omega^2}{\omega_0^2-\omega^2)^2+4\beta^2\omega^2}\right] \qquad (2.38)$$

As in the case of spontaneous emission and absorption, this result of the classical oscillator model must be modified to include the oscillator strength *f:*

$$n^2(\omega) - 1 = \frac{Ne^2 f}{\epsilon_o m}\left[\frac{\omega_0^2-\omega^2}{\omega_0^2-\omega^2)^2+4\beta^2\omega^2}\right] \qquad (2.39)$$

Unlike absorption, the refractive index is usually attributable to non-resonant transitions, that is, transitions such that, $|\omega_0^2 - \omega^2| \gg \beta\omega$ In this case:

$$n^2(\omega) - 1 \approx \left[\frac{Ne^2 f}{\epsilon_o m[\omega_0^2-\omega^2]}\right] \qquad (2.40)$$

In this non resonant situation, however, no one transition is necessarily dominant, and so we must add the contributions of all transitions connected to the ground state in which the atoms are presumed (for now) to reside. Thus, if the transitions from the ground state have oscillator strengths (f_j) and transition frequencies(ω_j) , the refractive index at the radiation frequency (ω) is given by the formula:

$$n^2(\omega) - 1 \approx \frac{Ne^2}{\epsilon_o m}\sum_j \frac{f_j}{\omega_j^2-\omega^2} \qquad (2.41)$$

This result applies when there is one type of atom or molecule in the medium; more generally we simply add the contributions of the different species. In a gas, furthermore, the density N is generally sufficiently low that $n^2(\omega) \approx 1$ and

Therefore $n^2 - 1 = (n-1)(n+1) \approx 2(n-1)$ Thus, for a gas consisting of a single type of atom or molecule with number density N, the formula for the refractive index is approximately:

$$n(\omega) = 1 + \frac{Ne^2}{2m\epsilon_o} \sum_j \frac{f_j}{\omega_j^2 - \omega^2} \tag{2.42}$$

It is interesting to relate this result to a formula that is often used in tabulations of the refractive index of gases. For this purpose, we first rewrite (2.42) in terms of radiation wavelength ($\lambda = \frac{2\pi c}{\omega}$) and transition wavelengths($\lambda_j = \frac{2\pi c}{\omega_j}$):

$$n(\omega) = 1 + \frac{Ne^2}{8\pi^2\epsilon_o mc^2} \sum_j \frac{f_j \lambda^2}{1 - \lambda_j^2/\lambda^2} \tag{2.43}$$

As noted, electronic resonance in molecules (and in many atoms) tends to lie in the ultraviolet, in which case $\lambda. \ll \lambda$ for optical wave length λ. In this case we can approximate $(1 - \lambda_j^2/\lambda^2)^{-1}$ by the first two terms of its binomial series expansion, $1 + \lambda_j^2/\lambda^2$: then,

$$n(\lambda) - 1 \approx A_1 \left(1 + \frac{B_1}{\lambda^2}\right) \tag{2.44}$$

Where $$A_1 = \frac{Ne^2}{8\pi^2\epsilon_0 mc^2} \sum_j f_j \lambda_j^2 \tag{2.45}$$

$$B_1 = \sum_j \lambda_j^4 \tag{2.46}$$

Where: A_1 and B_1 are Cauchy coefficients

An empirical relation of the form (2.44) was proposed by Cauchy in 1830, before the electromagnetic theory of light. Our derivation of Cauchy's formula gives explicit expressions for the coefficients A_1 and B_1. Unfortunately, it is difficult to calculate the numerical values of A_1 and B_1 for a given atom or molecule because we require the transition wavelengths and the oscillator strengths of all transitions connected to the ground state, including transitions to "Continuum" states in which the electrons are unbound, that is, in which an atom is ionized. For a gas at STP [P =760Torr, T = 273K, and, $N = 2.69 \times 10^{25}\,/m^3$],

$$A = 1.2x10^{10} \sum_j f_j \lambda_j^2 \quad (2.47)$$

Cauchy's formula correctly accounts for the fact that most transparent materials we encounter daily (e.g., water, air, glass) have refractive indices greater than unity at visible wavelengths. According to our analysis, this is a consequence of these materials having resonance wavelengths λj that are small compared to optical wavelengths (which lie roughly between 400 and 700 nm). It also follows from (2.44) that dn/dλ <0, which is also a familiar feature of refractive indices in the visible: A glass prism, for instance, causes violet to be dispersed more than red when it separates white light into its spectral components. In fact, the increase of n (λ) with decreasing λ(dn/dλ,<0) is sufficiently ubiquitous that it is called "normal dispersion." An example of norm appears in Fig. 2.6 [30].

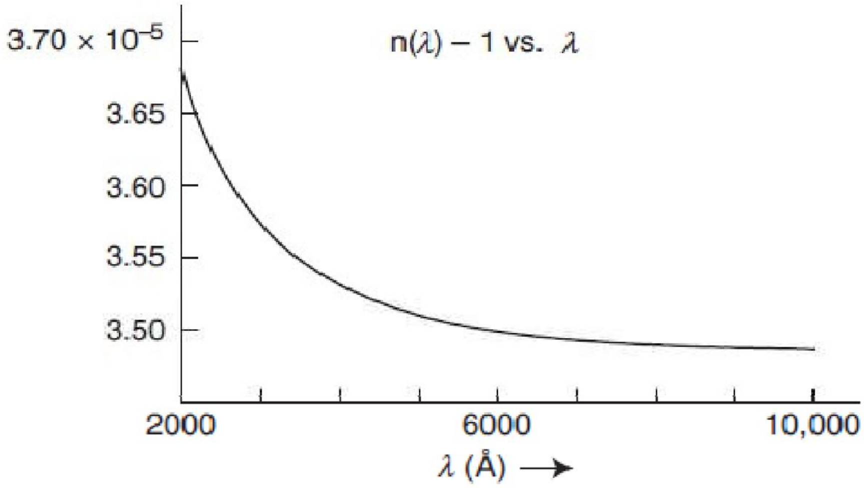

Figure: 2.6. Refractive index of helium at standard temperature and pressure.

CHAPTER THREE

Materials and Methods

In this chapter, the materials and methods employed in the thesis are presented. The first section of this chapter describes the various materials used for the experiment; the second section describes the methods of the research; and in the last section the experimental setup was presented.

3.1. Materials

Prism spectrometer, red and green diode laser and He-Ne laser are used as a light source. In addition to these, different instruments such as measuring cylinder to measure the volume of water, mercury thermometer and magnetic stirrer with hot plate were used. The samples are deionized water and pure glycerin extra zenith and clere.

3.2. Methods

3.2.1. Methods of measuring refractive index of glycerin solution by Snell's law

3.2.1.1. Preparation of Standard Solution of glycerin

For preparation of standard solution of glycerin the measured mass of glycerin added into a deionized water as volume fractions:10%, 20%, 30%, 40%, 50%,60%,70%, 80%,90% and 100%) for both extra zenith and clere pure glycerin. The glycerin completely dissolved using magnetic stirrer. A 10% concentration of glycerin means dissolving a 10ml of glycerin within 90ml of deionized water.

3.2.1.2. Method of measuring of angle of minimum deviation

In order to measure the angle of minimum deviation, the set up were arranged as shown in figure 3.1. The sample prepared for each concentration of glycerin solution was poured into the sample holder (Hollow prism) which is placed on the prism spectrometer and for each glycerin solution, the angles of minimum deviation have been measured three times using red (650 nm) and green (532 nm) diodes and He-Ne (632.8 nm) laser lights and the averages were calculated for both extra zenith and clere glycerin. The refractive index of each solution for both extra zenith and clere glycerin were calculated from angle of minimum deviation using equation (2.23).

3.2.2. Method of measuring temperature dependence of refractive index

In order to measure the temperature dependence of glycerin refractive index, each of the prepared solution of both extra zenith and clere glycerin were poured into a beaker and heated using magnetic stirrer with a hot plate until the temperature reached 65°C by placing the thermometer inside a solution. Then after, the solution is poured into the sample holder (Hollow prism), which is placed on the prism spectrometer; the angle of minimum deviation was measured at the interval of 5°C while the solution is cooling down from (65°C to 35°C) temperature. This was done using red (650 nm) and green (532 nm) diodes laser lights for 20%, 40% 60%, 80% and 100%. From the measured angle of minimum deviation the refractive index was calculated using equation (2.23) for each concentration. Numerical procedure of fitting the experimental data was carried out by linear curve fitting based on Levenberg-Marquardt algorithm using origin 8 software for correlation.

3.3. Experimental set up

Experimental set up for determination of angle of minimum deviation for glycerin solution.

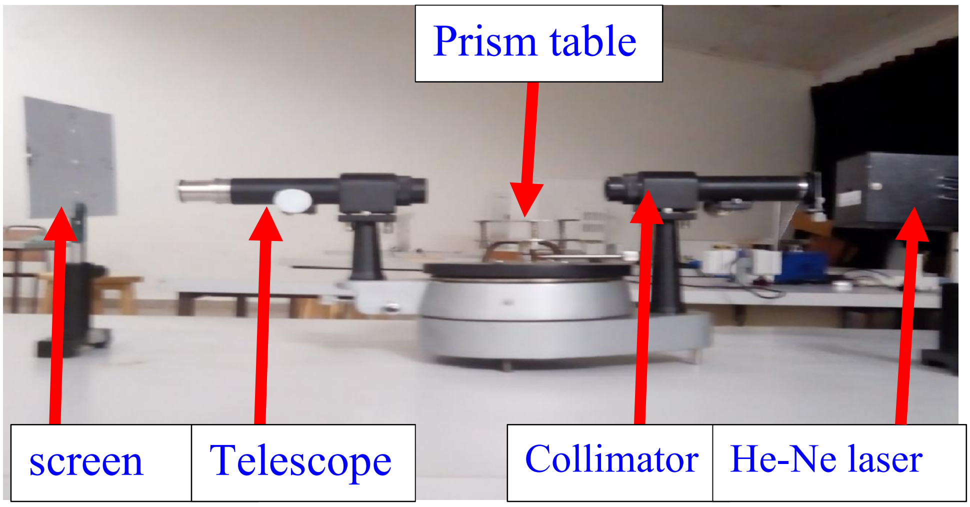

Figure: 3.1. Experimental setup for determination of angle of minimum deviation

Figure: 3.2. Equilateral hollow prism

CHAPTER FOUR

Result and Discussion

In this chapter, the results and discussion of the thesis were presented.

4.1. Refractive index of glycerin solution using red and green diode lasers and He-Ne laser

4.1.1. Concentration dependent of refractive index of glycerin solutions

Table: 4.1 Results of refractive index for Glycerin solution for different concentration, determined using red diode laser (λ = 650 nm).

Glycerin concentration (%)	Angle of minimum deviation(°) (extra zenith)	Refractive index	Angle of minimum deviation(°)(clere)	Refractive index
10	22.68	1.3210	23.53	1.3321
20	23.45	1.3311	24.33	1.3425
30	24.33	1.3426	25.13	1.3528
40	25.36	1.3558	26.38	1.3689
50	26.41	1.3692	27.25	1.3799
60	27.54	1.3835	28.37	1.394
70	28.72	1.39827	29.67	1.4101
80	29.84	1.4122	30.71	1.4229
90	31.38	1.4312	32.01	1.4388
100	32.04	1.4392	32.95	1.4502

Table 4.1 shows the refractive indices of glycerin solution measured at different concentrations using red diode laser (λ = 650 nm). The results in the table indicate that the refractive index of the solutions in the mentioned concentration range (10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% &100%) were found to be 1.3210 to 1.4392 for extra zenith and 1.3321 to 1.4502 for clere glycerin, using red diode laser. This values of refractive index was calculated from the measured angle of minimum deviation using equation (2.23) for each concentration. The refractive index increases linearly as the concentration of glycerin solution increases. The real refractive index of pure glycerin (100%) was found to be1.4392 for extra zenith and 1.4502 for clere glycerin. The obtained results of both extra zenith and clere glycerin are comparable with the one found by Hoyt which was 1.47399 at 20°c. the value was determined by using sodium lamp as a source of light (λ=589nm) [24] and they are in good agreement with it.

The values in table 4.1 also shows that the clere is more related to standard value of glycerin than the extra zenith. Both extra zenith and clere glycerin are glycerin but have different refractive indices for the same concentration. This means the results of the experiment indicate that the extra zenith has less quality than the clere glycerin which is more concentrated. Even though the quality is affected by other factor that can may revealed by complex refractive index.

Table: 4.2 Results of refractive index for Glycerin solution for different concentration, determined using green diode laser (λ = 532 nm).

Glycerin concentration (%)	Angle of minimum deviation(^{o}) (extra zenith)	Refractive index	Angle of minimum deviation(^{o})(clere)	Refractive index
10	24.39	1.3433	25.77	1.3611
20	25.20	1.3537	26.89	1.3753
30	26.21	1.3667	27.78	1.3865
40	27.35	1.3811	28.68	1.3978
50	28.72	1.3983	29.56	1.4088
60	29.95	1.4136	30.78	1.4238
70	31.07	1.4274	31.89	1.4373
80	32.26	1.4418	32.93	1.4499
90	33.22	1.4534	33.76	1.4598
100	33.76	1.4598	34.78	1.4719

Table 4.2 shows the refractive indices of glycerin solution measured at different concentrations using Green diode laser (λ = 532nm). The results in the table indicate that the refractive index of the solutions in the mentioned concentration range (10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% &100%)) were found to be 1.3433to 1.4598 for extra and 1.3611 to 1.4719 for clere glycerin, using green diode laser which is in good agreement with expected results[24]. This values of refractive index was calculated from the measured angle of minimum deviation using equation (2.23) for each concentration. The refractive index increases linearly as the concentration of glycerin solution increases. The real refractive index of pure glycerin (100%) was found to be1.4598 for extra zenith glycerin and 1.4719 for clere glycerin. The obtained results of both extra zenith and clere glycerin are comparable with the one found by Hoyt which

is 1.47399 at 20ºc. the value was determined by using sodium lamp as a source of light (λ=589nm) [24] and they are in good agreement with it.

The values in table 4.2 also shows that the clere is more related to standard value of glycerin than the extra zenith. Both extra zenith and clere glycerin are glycerin but have different refractive indices for the same concentration. This means the results of the experiment indicate that the extra zenith has less quality than the clere glycerin which is more concentrated. Even though the quality is affected by other factor that can may revealed by complex refractive index.

Table: 4.3 Results of Refractive index for glycerin solution of different concentration, determined using He-Ne laser (λ = 632.8 nm)

Glycerin conce ntration (%)	Angle of minimum deviation(º) (extra zenith)	Refractive index	Angle of minimum deviation(º)(clere)	Refractive index
10	22.85	1.3233	24	1.3383
20	23.96	1.3377	24.61	1.3462
30	24.60	1.3460	25.73	1.3606
40	25.65	1.3595	26.72	1.3732
50	26.67	1.3725	27.51	1.3832
60	27.97	1.3889	28.8	1.3993
70	29.22	1.4046	30.04	1.4147
80	30.42	1.4194	31.09	1.4276
90	31.75	1.4356	32.29	1.4422
100	32.92	1.4498	33.79	1.4602

Table 4.3 shows the refractive indices of glycerin solution measured at different concentrations using He-Ne laser (λ = 632.8nm). The results in the table indicate that the refractive index of the solutions in the mentioned concentration range (10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% &100%)) were found to be 1.3233 to 1.4498 for extra zenith and 1.3383 to 1.4602 for clere glycerin, using He-Ne laser which is in good agreement with expected results[24]. This values of refractive index was calculated from the measured angle of minimum deviation using equation (2.23) for each concentration. The refractive index increases linearly as the concentration of glycerin solution increases. The real refractive index

of pure glycerin (100%) was found to be1.4498 for extra zenith) and 1.4602for clere. The obtained results of both extra zenith and clere are comparable with the one found by Hoyt which is 1.47399 at 20°c. the value was determined by using sodium lamp as a source of light (λ=589nm) [24] and they are in good agreement with it.

The values in table 4.3 also shows that the clere is more related to standard value of glycerin than the extra zenith. Both clere and extra zenith are glycerin but have different refractive indices for the same concentration. This means the results of the experiment indicate that the extra zenith has less quality than the clere which is more concentrated. Even though the quality is affected by other factor that can may revealed by complex refractive index.

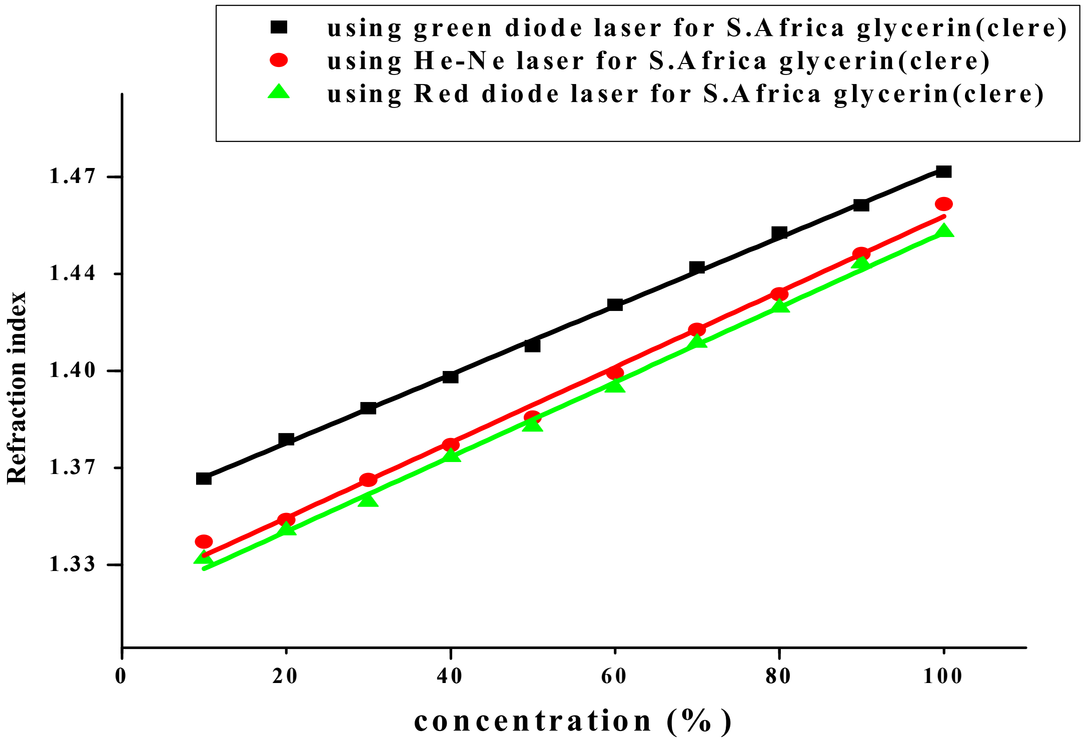

Figure: 4.1 graph of refractive index versus concentration using red, green diode and He-Ne lasers for South African glycerin (clere).

Table: 4.4 Results of refractive index versus concentration graph for the three lasers (red diode green diode and He-Ne) laser.

Source	Slopes	Intercepts	R^2	Regression equations
Red diode laser	0.00135±2.36E-5	1.315±0.00147	0.99724	n = 0.00132 c +1.33
Green diode laser	0.00124±50E-5	1.349±9.33E- 4	0.99867	n = 0.00123c + 1.33
He-Ne laser	0.00136±3.29E-5	1.319±0.00204	0.99475	n = 0.00132 c +1.33

where c is concentration of glycerin solution.

The graph indicates that the refractive index increases linearly as the concentration of glycerin solution increases. As shown in the figure the experimental values are best linearly fitted (R^2 = 0.99724, 0.99718, 0.99461) for red diode, green diode and He-Ne laser respectively.

Table 4.4 shows the refractive index calculated by our techniques using red diode, green diode lasers and He-Ne laser light. The obtained results are almost agreed with the previous reported results [24].

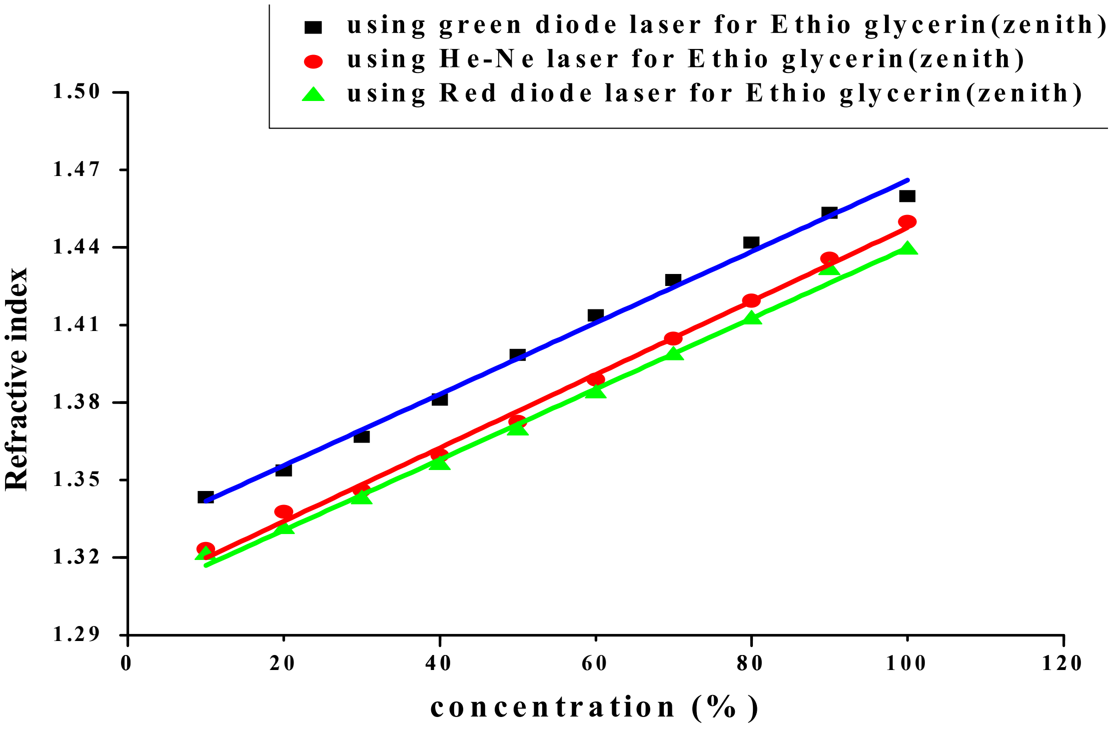

Figure: 4.2 graph of refractive index versus concentration using red, green diode and He-Ne lasers for Ethiopian glycerin (zenith).

Table: 4.5 Results of refractive index versus concentration graph for the three lasers (red diode green diode and He-Ne) laser for Ethiopian glycerin (zenith).

Source of light	Slopes	Intercepts	R^2	Regression equations
Red diode	0.00142±3.241E-5	1.304±0.00185	0.99574	n = 0.00132 c +1.313
Green diode	0.00138±3.61E-5	1.328±0.00224	0.99384	n = 0.00123c + 1.313
He-Ne	0.00142±3.241E-5	1.305±0.00201	0.99533	n = 0.00132c + 1.313

Where c is concentration of glycerin solution.

The graph indicates that the refractive index increases linearly as the concentration of glycerin solution increases. As shown in the figure the experimental values are best linearly fitted. (R^2 =0.99574, 0.99384 and 0.99533) for red diode, green diode and He-Ne laser respectively for Ethiopian glycerin (zenith).

Table 4.5 shows the refractive index calculated by our techniques using red diode, green diode lasers and He-Ne laser light. The obtained results are almost agreed with the previous reported results [24].

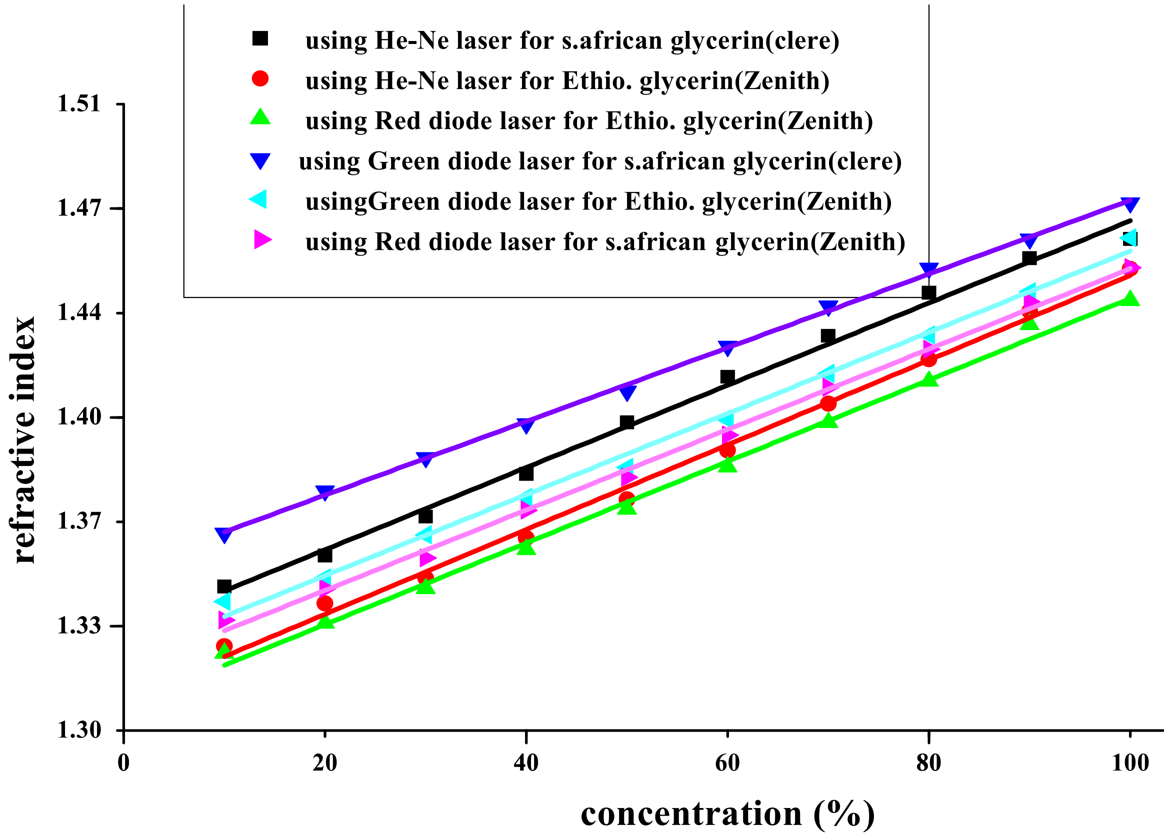

Figure: 4.3 graph of refractive index versus concentration of Ethiopian glycerin (zenith) and S.Africa glycerin (clere) using red, green diode and He-Ne lasers

The graph indicates that the refractive index increases linearly as the concentration of glycerin solution increases. As shown in the figure the experimental values are best linearly fitted (R^2 =0.99574, 0.99384 and 0.99533) for Ethiopian glycerin (zenith) and (R^2 = 0.99724, 0.99718, 0.99461) for S.Africa glycerin (clere) using red diode, green diode and He-Ne laser respectively. The curves in figure 4.3 shows that the South African glycerin (clere) is more related to standard value of glycerin than the Ethiopian glycerin (zenith). Both South African glycerin (clere) and Ethiopian glycerin (zenith) are glycerin but have different refractive indices for the same concentration. This means the results of the experiment may indicate that the Ethiopian glycerin (zenith) has less quality than the South African glycerin (clere) which is more concentrated. This quality is not approved perfectly by investigating real refractive index only there might be other factor that affect it, which might be determined by complex refractive index.

Table: 4.6. The table of refractive indices, experimental value and the literatures values

Concentration (%)	Experimental values Using red diode (λ = 650nm)		Experimental values Using He-Ne diode (λ = 632.8nm)		Experimental values Using red diode (λ = 532nm)		Literatures value (λ = 589.29nm) [24]
	Ethiopia	S.Africa	Ethiopia	S.Africa	Ethiopia	S.Africa	
10	1.321	1.3321	1.3233	1.3383	1.3433	1.3611	1.3448
20	1.3311	1.3425	1.3377	1.3462	1.3537	1.3753	1.3575
30	1.3426	1.3528	1.346	1.3606	1.3667	1.3865	1.3707
40	1.3558	1.3689	1.35952	1.3732	1.3811	1.3978	1.3841
50	1.3692	1.3799	1.3725	1.3832	1.3983	1.4088	1.3981
60	1.3835	1.394	1.3889	1.3993	1.4136	1.4238	1.4129
70	1.39827	1.4101	1.4046	1.4147	1.4274	1.4373	1.4279
80	1.4122	1.4229	1.4194	1.4276	1.4418	1.4499	1.4429
90	1.4312	1.4388	1.4356	1.4422	1.4534	1.4598	1.4584
100	1.4392	1.4502	1.4498	1.4602	1.4598	1.4719	1.4739

4.1.2. Wavelength dependence of the refractive index of glycerin solutions

Figure 4.4 shows the refractive index versus wavelength graph for different lasers. The graph indicates the refractive index of glycerin (Ethiopian, zenith) solutions exponentially decreases as the wavelength of the laser light increases. Hence the obtained results are in a good agreement as shown in figure 2.6.

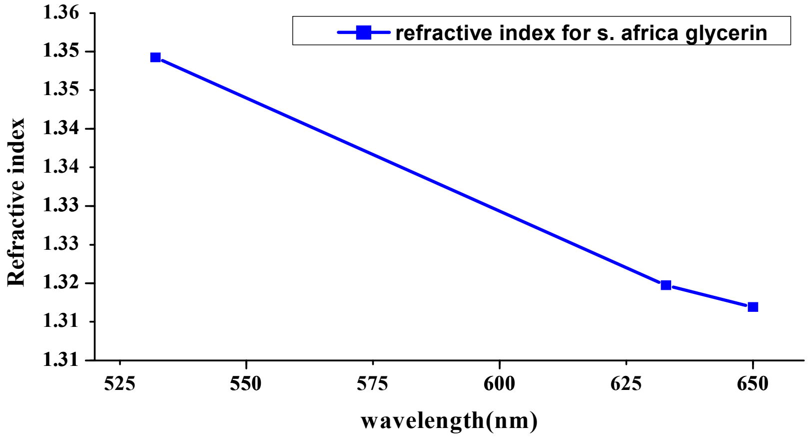

Figure 4.4 the refractive index versus wavelength graph for different lasers for South African glycerin (clere).

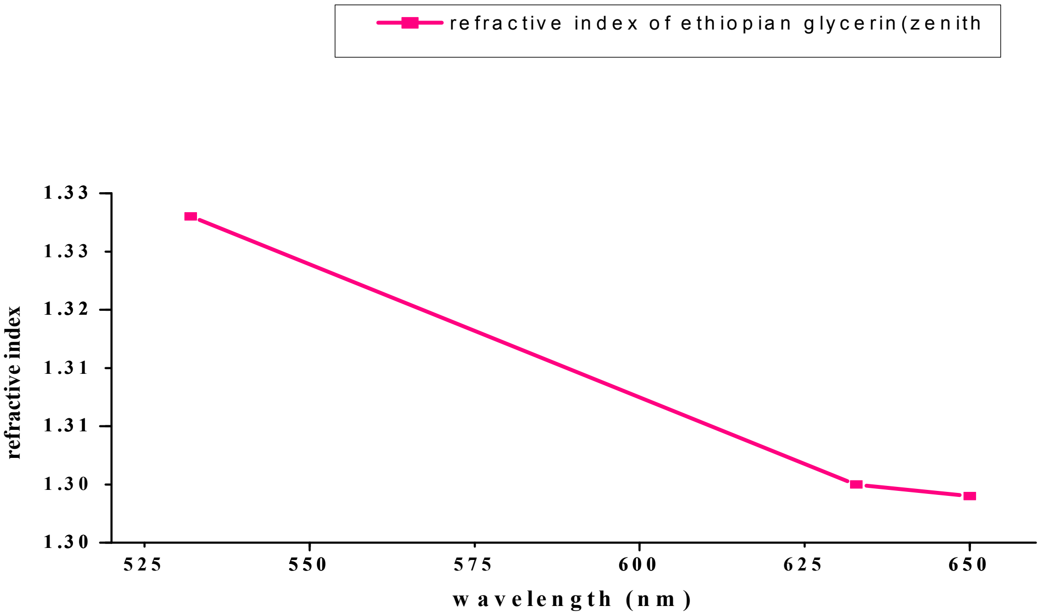

Figure 4.5 the refractive index versus wavelength graph for different lasers for Ethiopian glycerin (zenith).

Figure 4.4 and 4.5 shows the refractive index versus wavelength graph for different lasers for Ethiopian glycerin (zenith) and South Africa glycerin (clere). The graph indicates the refractive index of glycerin solutions exponentially decreases as the wavelength of the laser light increases. Hence the obtained results are in a good agreement with the theoretical description expressed in equation (2.44). In equation (2.44), the refractive index decreases exponentially as the wavelength of laser light increasing as shown in figure 2.6.

4.1.2. Temperature dependent of refractive index of glycerin solutions using Green and red diode lasers

Table: 4.7 Results of refractive index for glycerin solution at different temperatures and concentrations, determined using red diode laser (λ = 650 nm) for both South African glycerin (clere) and Ethiopian glycerin (zenith).

	glycerin concentrations (%)		Temperature(°c)						
			65	60	55	50	45	40	35
Refractive indices	20	Ethiopia	1.3049	1.309	1.3125	1.3154	1.3182	1.3205	1.3252
		S. Africa	1.317	1.3211	1.3246	1.3275	1.3303	1.3326	1.3373
	40	Ethiopia	1.3222	1.3263	1.3298	1.3327	1.3355	1.3378	1.3425
		S. Africa	1.3393	1.3434	1.3469	1.3498	1.3526	1.3549	1.3596
	60	Ethiopia	1.3658	1.368	1.3702	1.3724	1.3746	1.3768	1.379
		S. Africa	1.3746	1.3769	1.3788	1.3804	1.3846	1.3873	1.3895
	80	Ethiopia	1.3903	1.3925	1.3947	1.3969	1.3991	1.4013	1.4035
		S. Africa	1.3968	1.3991	1.401	1.4026	1.4068	1.4095	1.4117
	100	Ethiopia	1.4019	1.4054	1.4089	1.4124	1.4159	1.4194	1.4229
		S. Africa	1.4142	1.4172	1.4218	1.4241	1.4285	1.4318	1.4353

Table: 4.7 shows the refractive index of glycerin solutions at different temperature. As shown in the table, the refractive index of glycerin solutions decrease as the temperature increases. In the mentioned temperatures (35^0C, 40^0C, 45^0C, 50^0C, 55^0C, 60^0C and 65^0C), The minimum value of refractive index of the glycerin solution at the temperature of 65^0C were found to be 1.3049 for Ethiopian glycerin (zenith) and 1.3170 for South African glycerin (clere) on 20% concentration and the maximum value were found to be 1.4229 for Ethiopian glycerin (zenith) and 1.4353 for South African glycerin (clere) at 35^0C for 100% concentration using red diode laser. These results are in a good agreement with the reported results by [32].

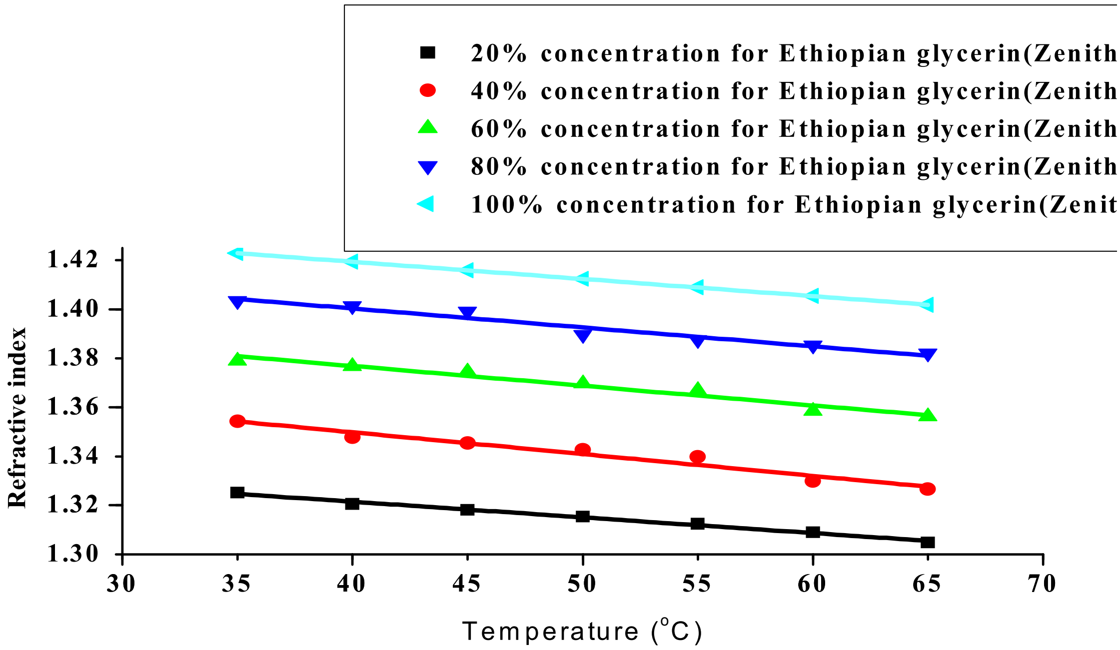

Figure: 4.6 Graph of refractive index versus temperature for 20%, 40%, 60%, 80% and 100% of glycerin (Ethiopian) solution using red diode laser as a light source.

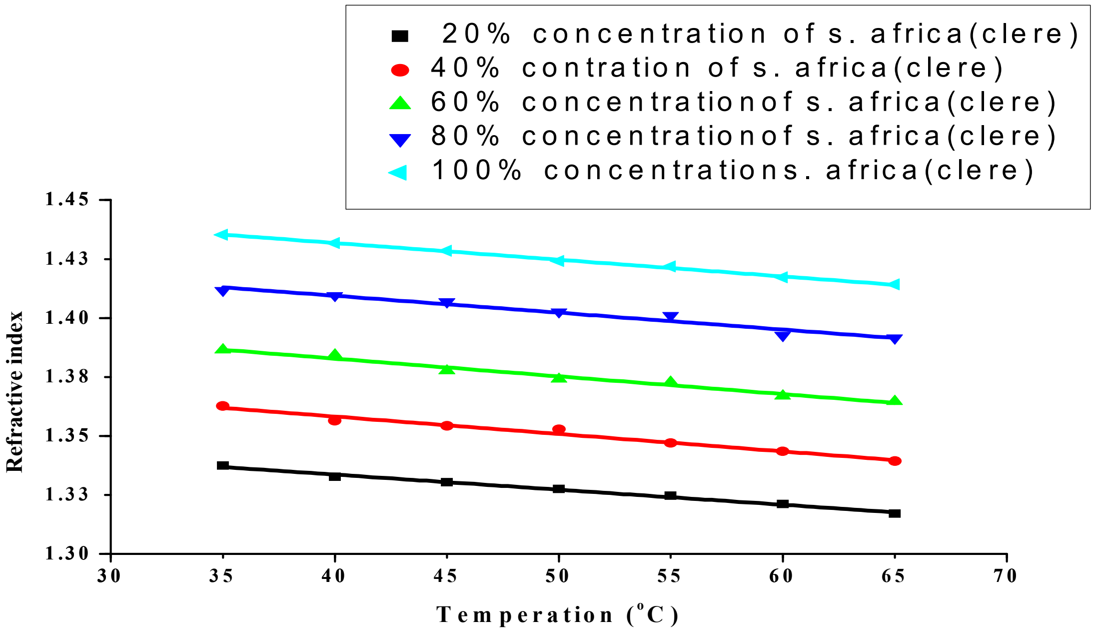

Figure: 4.7 Graph of refractive index versus temperature for 20%, 40%, 60%, 80% and 100% of glycerin (South Africa) solutions using red diode laser as a light source.

Figure 4.6 and 4.7 shows the graph of refractive index versus concentration of glycerin solution measured using Red diode laser for both South African glycerin (clere) and Ethiopian glycerin (zenith). As shown in the graph the experimental values are best linearly fitted (R^2 = 0.99103, 0.95052, 0.95407, 0.94614 and 0.99999) and (R^2 = 0.99103, 0.9764, 0.97451, 0.95397and 0.9965) with negative slope as shown in table 4.8 and 4.9 for both Ethiopian glycerin (zenith) and South African glycerin (clere) respectively.

Table: 4.8 Results of slopes and intercept for refractive index versus temperature graph for 20%, 40%, 60%, 80% and 100% together for Ethiopian glycerin (zenith) using red diode laser.

Red diode laser	Concentration 20%	Concentration 40%	Concentration 60%	Concentration 80%	Concentration 100%
Adj.R-Square	0.99103	0.95052	0.95407	0.94614	0.99999
Intercept	1.3471± 0.00127	1.38538± 0.0042	1.40903± 0.00366	1.43124± 0.00382	1.4474± 1.8636E-6
Slope (dn/dT)	-6.4E-4± 2.48424E-5	-8.88929E-4 ±8.24409E-5	-8.03833E-4 ±7.17131E-5	-7.72429E-4 7.48856E-5	-7E-4± 3.65482E-8

Table: 4.9 Results of slopes and intercept for refractive index versus temperature graph for 20%, 40%, 60%, 80% and 100% together for South African glycerin (zenith) using Red diode laser.

Green diode laser	Concentration 20%	Concentration 40%	Concentration 60%	Concentration 80%	Concentration 100%
Adj.R-Square	0.99103	0.9764	0.97451	0.95397	0.9965
Intercept	1.3592± 0.00127	1.38776± 0.00239	1.41286± 0.00253	1.43804± 0.00326	1.46013± 8.74118E-4
Slope (dn/dT)	-6.4E-4± 2.48424E-5	-7.38857E-4±4.6803E-5	-7.52143E-4±4.9557E-5	-7.16E-4± 6.39537E-5	-7.08571E-4±1.7142E-5

Table: 4.10 Results of refractive index for glycerin solution at different temperatures and concentrations, determined using green diode laser (λ = 532 nm).

	Glycerin concentration (%)		Temperature(°c)						
			65	60	55	50	45	40	35
Refractive indices	20	Ethiopian	1.3445	1.3472	1.3501	1.3536	1.3562	1.3578	1.3603
		S. African	1.3561	1.3588	1.3617	1.3652	1.3678	1.3694	1.3719
	40	Ethiopian	1.3602	1.3629	1.3658	1.3693	1.3719	1.3735	1.376
		S. African	1.3769	1.3796	1.3825	1.386	1.3886	1.3902	1.3927
	60	Ethiopian	1.3933	1.396	1.3989	1.4024	1.405	1.4066	1.4091
		S. African	1.4035	1.4062	1.4091	1.4126	1.4152	1.4168	1.4193
	80	Ethiopian	1.4119	1.4146	1.4175	1.421	1.4236	1.4252	1.4277
		S. African	1.42	1.4227	1.4256	1.4291	1.4317	1.4333	1.4358
	100	Ethiopian	1.4267	1.4294	1.4323	1.4358	1.4384	1.44	1.4425
		S. African	1.4388	1.4415	1.4444	1.4479	1.4505	1.4521	1.4546

Table: 4.10 shows the refractive index of glycerin solutions at different temperature. As shown in the table, the refractive index of glycerin solutions decrease as the temperature increases. In the mentioned temperatures (35^{0}C, 40^{0}C, 45^{0}C, 50^{0}C, 55^{0}C, 60^{0}C and 65^{0}C), The minimum value of refractive index of the glycerin solution at the temperature of 65^{0}C were found to be 1.3445 for Ethiopian glycerin (zenith) and 1.3561for South African glycerin (clere) on 20% concentration and the maximum value were found to be 1.4425 for Ethiopian glycerin (zenith) and 1.4546 for South African glycerin (clere) at 35^{0}C for 100% concentration using green diode laser. These results are in a good agreement with the reported results by [32]

Figure: 4.8. Graph of refractive index versus temperature for 20%, 40%, 60%, 80% and 100% of glycerin solution using Green diode laser as a light source for Ethiopian glycerin (zenith).

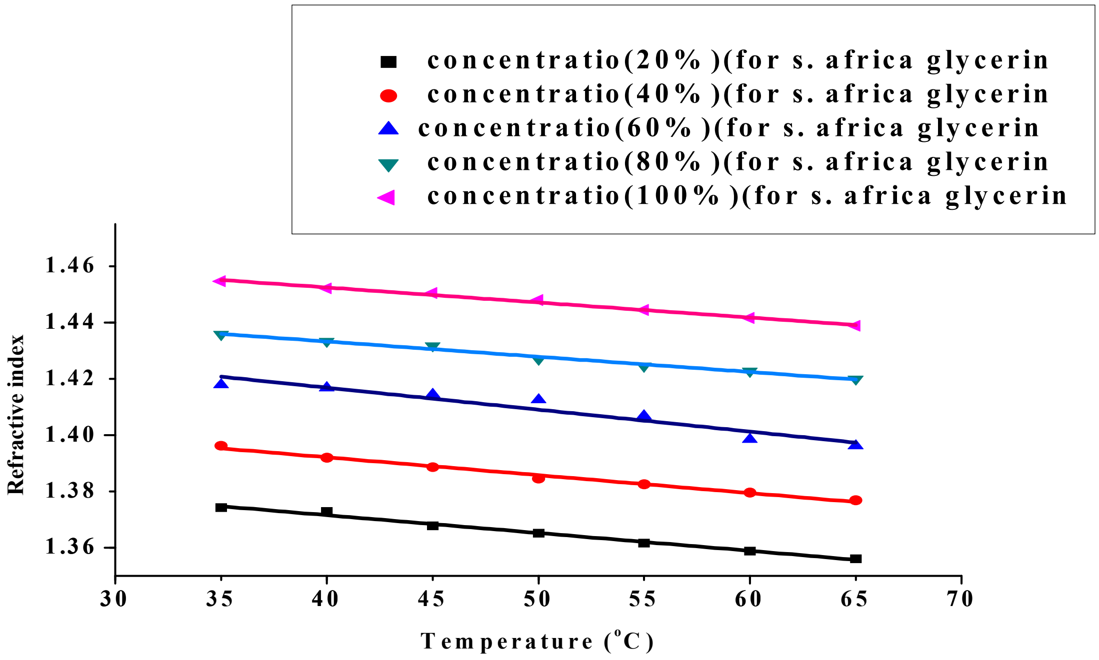

Figure: 4.8. Graph of refractive index versus temperature for 20%, 40%, 60%, 80% and 100% of glycerin solution using Green diode laser as a light source for Ethiopian glycerin(zenith).

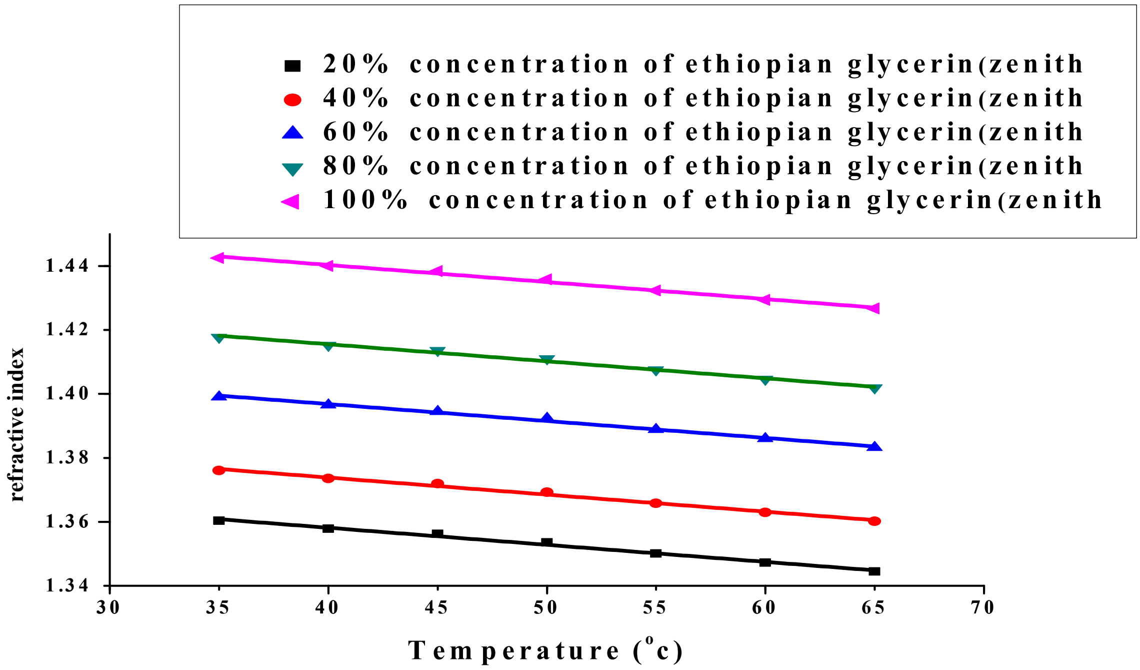

Figure: 4.9. Graph of refractive index versus temperature for 20%, 40%, 60%, 80% and 100% of glycerin solution using Green diode laser as a light source for S.Africa glycine(clere).

Figure 4.8 and 4.9. Shows the graph of refractive index versus concentration of glycerin solution measured using Green diode laser for both Ethiopian glycerin (zenith) and South African glycerin (clere). As shown in the graph the experimental values are best linearly fitted (R^2 = 0.98985, 0.98985, 0.9928, 0.98985 and 0.98985) and (R^2 = 0.98806, 0.98777, 0.90921, 0.98437 and 0.98985) with negative slope as shown in table 4.7 and 4.8 for both Ethiopian glycerin (zenith) and South African glycerin (clere) using Green diode laser respectively.

Table: 4.11 Results of slopes and intercept for refractive index versus temperature graph for 20%, 40%, 60%, 80% and 100% together for Ethiopian glycerin (zenith) using Green diode laser.

Green diode laser	Concentration 20%	Concentration 40%	Concentration 60%	Concentration 80%	Concentration 100%
Adj.R-Square	0.98985	0.98985	0.9928	0.98985	0.98985
Intercept	1.37949± 0.00112	1.39519± 0.00112	1.41804± 9.39083E-4	1.43689± 0.00112	1.46169± 0.00112
Slope (dn/dT)	-5.33571E-4 ±2.20366E-5	-5.33571E-4 ±2.20366E-5	-5.3E-4± 1.84169E-5	-5.33571E-4 ±2.20366E-5	-5.33571E-4 ±2.20366E-5

Table: 4.12 Results of slopes and intercept for refractive index versus temperature graph for 20%, 40%, 60%, 80% and 100% together for South African glycerin (clere) using Green diode laser.

Green diode laser	Concentration 20%	Concentration 40%	Concentration 60%	Concentration 80%	Concentration 100%
Adj.R-Square	0.98806	0.98777	0.90921	0.98437	0.98985
Intercept	1.39691± 0.00145	1.41759± 0.00147	1.44809± 0.00509	1.4549± 0.00142	1.47379± 0.00112
Slope (dn/dT)	-6.33214E-4 ±2.83847E-5	-6.36071E-4 ±2.8868E-5	-7.80736E-4 ±9.98951E-5	-5.41E-4± 2.77923E-5	-5.33571E-4 ±2.20366E-5

CHAPTER FIVE

5. Conclusions and Recommendations

5.1. Conclusions

In this work a simple method, hollow prism spectrometer was presented to determine the refractive index of glycerin solutions. Experiment results showed that this technique could be safely study the dependence of refractive index of glycerin solutions, on concentration, on temperature as well as on the wavelength. The experimental result shows that the value of refractive index of glycerin solutions were Increases linearly as the concentration of glycerin increases, Decreases linearly as the temperature increases with negative slope and exponentially decreases as the wavelength of light increases and the real refractive index of pure glycerin of extra zenith and clere were investigated and compared with refractive index done by other researcher and they are in good agreement. In addition their values were compared: the refractive index of clere glycerin is more related to standard value of glycerin than that of the extra zenith. This means that relatively the clere glycerin has greater quality than that of the extra zenith.

It should be stated that temperature and availability of equipment had effect(s) on the results determined in this study but within the experimental limitation, the results are consistent and tolerable.

5.2. Recommendations

The methods we used can also be applied for other types of solutions. On top of this, in a future work, the hollow prism made by expert or industrially made would need to be used to provide better predictive results. The research is conducted on real refractive index to insure the quality of glycerin this is not enough to do so, because there are other factors that affect the quality. Therefore other researcher may work on complex refractive index for future to insure the quality of glycerin more.

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