Diffraction Grating and a Plano Convex Lens Refractometer

Shyam Singh[1*]

[1]Physics Department, University of Namibia, Private Bag 13301, Windhoek, Namibia

Received: 22nd August, 2015. Accepted: 23rd May, 2016. Published: 15th August, 2016.

Abstract

This paper describes a method of finding the refractive index of liquids using a thin plano-convex lens and a transmission diffraction grating. Light from a low power helium-neon laser is diffracted by a transmission diffraction grating and the diffracted light is received by the thin plano-convex lens L and focuses it at the image distance v. A formula is derived to calculate the refractive index of experimental liquid at a particular temperature.

Keywords: Refractive index, plano-convex lens, diffraction grating.

ISTJN 2017; 9:107-111.

1 Introduction

A spherical concave mirror was used (1) to find the refractive index of a transparent liquid using Snell's law. Recently, Kumar (7) discussed a displacement method for measuring the refractive index of liquids. Several authors (2-6) have discussed various methods to determine the refractive index of liquids. Yet there is always a need to develop more simple and accurate techniques for the measurements of refractive index of liquids. In the present paper, we describe a simple and inexpensive method for measuring the refractive index of liquids using a low power He-Ne laser and a thin liquid plano-convex lens has been discussed. The results obtained have been compared with the standard values.

*Corresponding author: E-mail: ssingh@unam.na; Fax: 264-61-206-3791

2 Principle and Method

As shown in Figure 1, light from He-Ne laser is diffracted by a grating and then is focused by the plano-convex lens on to a horizontal screen. The value of the focal length fw when the plano-convex lens is filled with distilled water is calculated using Equation 1.

$$1/f_w = 1/v_r – 1/u_r \tag{1}$$

where u_r and v_r are the object and image distances for a reference liquid from the lens respectively. The formula (1) is used to check the focal length of the plano-convex lens with respect to the reference liquid (say distilled water). We assume the walls of the lens to be very thin so that the refraction takes place in the liquid lens as shown in Figure 1.

Now the distilled water is replaced by the experimental liquid. The parallel light will focus at f_L to get two equations as follows:

$$1/f_w = ({}_a n_w – 1)(1/R_1 – 1/R_2) = ({}_a n_w – 1)(C_1 – C_2) \quad \text{with distilled water} \tag{2}$$

$$1/f_L = ({}_a n_L – 1)(C_1 – C_2) \quad \text{with experimental liquid.} \tag{3}$$

Here, we can take $R_2 = \infty$ and $R_1 = R$ for a thin plano-convex lens so that these two equations will give

$$ {}_a n_L = 1 + K/f_L \tag{4}$$

where $K = f_w({}_a n_w – 1) = 6.6624$ is a constant for a distilled water-lens combination when the focal length of the plano-convex lens when filled with distilled water is taken as 20 cm. The terms ${}_a n_w$ gives the refractive index of water with respect to air and similarly ${}_a n_L$. The standard value of the refractive of water has been taken as 1.3312 and that of air as 1.0000. As can be seen in the formula 4, the refractive index of an experimental liquid, n_L depends on the choice of the liquid only and varies with liquid to liquid as f_L will vary with liquid.

3 Measurements and Results

The experimental setup is shown in Figure 1. The focal length of the distilled water-lens is calculated using Equation 1. The distilled water-lens means that the plano-convex lens is filled with distilled water. Now the lens is filled with experimental liquid and the focal length f_L of experimental liquid lens is obtained by measuring the object and image distance u and v respectively with the help of a position detector. Then the refractive index of the experimental liquid can be obtained using Equation 4.

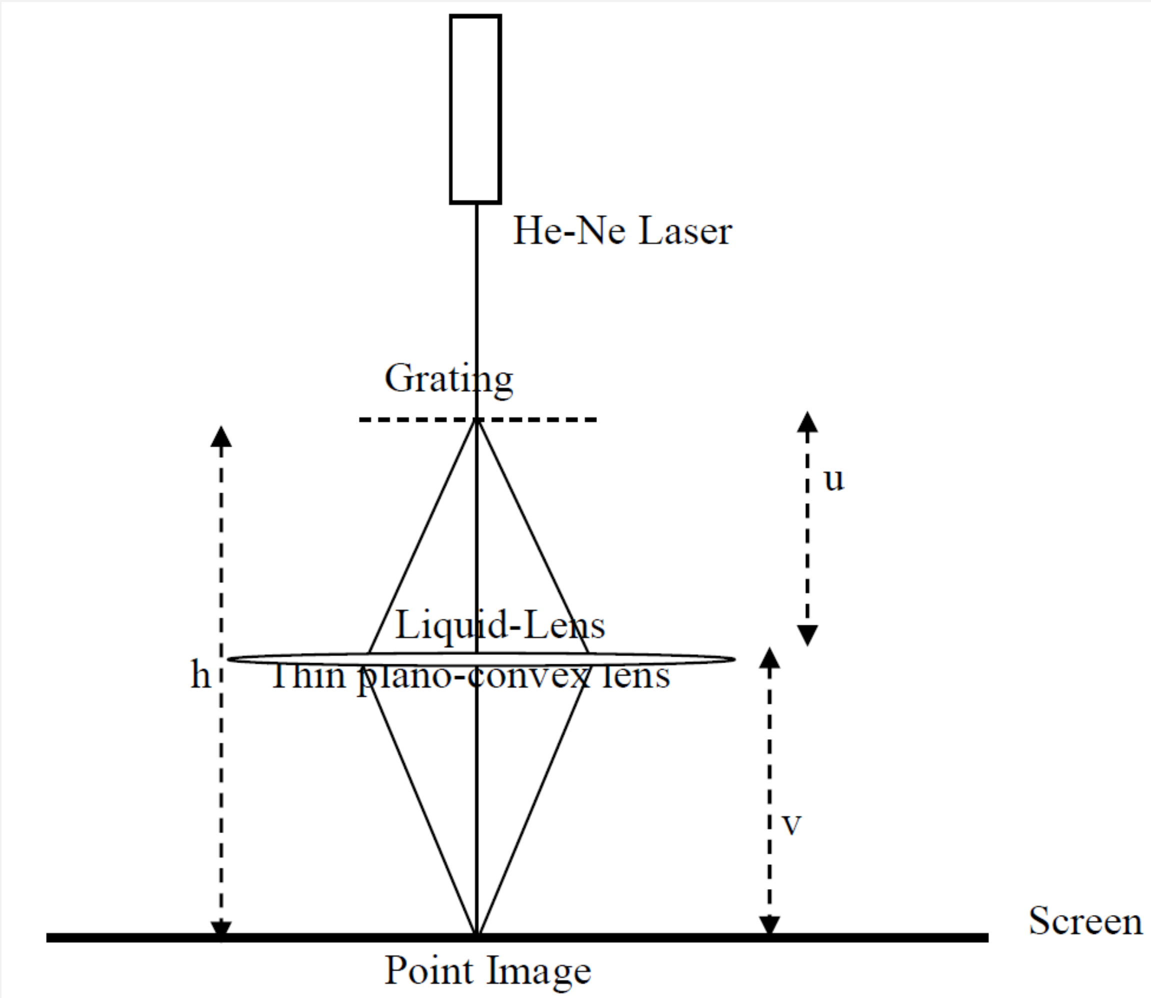

Figure 1: Liquid plano-convex lens.

Table 1: Value of focal length of liquid lens medium at $25° \pm 1°$

Liquid medium in hollow lens	$K = f_w({}_a n_w - 1)$ =20(1.3312-1)	Value of f_L	Value of ${}_a n_L = 1 + K/f_L$
Water	6.624	20	1.3312
Xylol	6.624	13.336	1.4967
Banzol	6.624	13.259	1.4996

The values of the refractive index of different liquids are given in Table 1. The refractive index of water at different temperature is shown in Table 2. If the refractive index of liquid is found different from the standard value, it will confirm an adulteration in liquids.

Table 2: Summary of factors for the success of ERP implementation

Liquid medium in hollow lens	This study	Standard value of refractive index
Water at 0°	1.3334	1.333463
Water at 20°	1.3333	1.33283
Water at 25°	1.3312	1.3311

4 Conclusion

A simple, inexpensive and yet comparably accurate method for the measurement of refractive index of liquid has been discussed. The experimental results of various liquids have been compared with the standard values. The importance of the method can be emphasized on the basis of its costs and simplicity. It can be seen that the refractive index of the liquid depends on the focal length of the lens filled with liquid only. A linear scale can be drawn to obtain an instant value of the refractive index of liquid since other parameters are constant. This method can further be improved by using electronics so that a handy instrument could be developed for instant checking of adulteration in liquids.

Acknowledgements

The financial support from the University of Namibia (UNAM) to do this experiment is greatly acknowledged.

References

[1] Joshi A and Serna J D, 'Refractive index of a transparent liquid measured with a concave mirror', PACS numbers: 01.50.Pa.42.15.-i.01.30.lb (2012).

[2] Nemoto S, 'Measurement of the refractive index of liquid using laser beam displacement', Applied Optics, 31, 6690 (1992).

[3] McCay M H, Semak V V, Hopkins J A, and Blaha B, 'Refractive index of NH4Cl-H2O as a function of wavelength: the effect of temperature and concentration', Applied Optics, 35, 3715 (1996).

[4] Khashan M A and Nassif A Y, 'Accurate measurement of the refractive indices of solids and liquids by the double layer interferometer', Applied Optics, 39, 5991 (2000).

[5] R S Kasana and A K Deshmukh, International Journal of Pure Applied Physics, 6, 263-268 (2010).

[6] A K Deshmukh and R S Kasana, International Journal of Physics and Application, 2, 51-55 (2010).

[7] Kumar S, 'Refractive index of liquids by measuring Displacement of Refracted Laser Beam'. Res. J. Physical Sci., 8, 6-9 (2013).