Physics 257, Section One, Lab Six: Michelson Interferometer

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1 Data and Results

Apparatus no. 8

1.1 Part 1

Table 1 shows the data from Part 1.

1.2 Part 2

Table 2 shows the data from Part 2.

Table 3 shows the conclusion we reached. The index of refraction of air was measured to be 1.000248722.

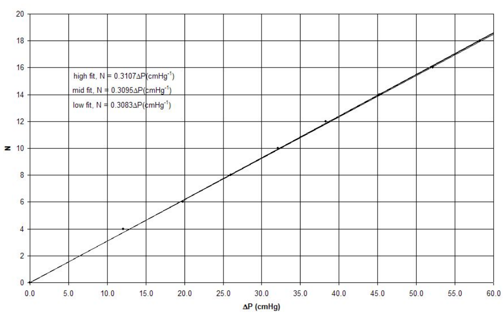

Figure 1: N *vs* ΔP

2 Conclusion

2.1 Chris Payette

(Ed: I do'n't have Chris'.)

2.2 Neil Edelman

Using a Michelson Interferometre, the wavelength of a beam of laser light was measured to be $643.4nm$, a 0.25% difference from the accepted value of $632.8nm$. With this calibration, the index of refraction of air was measured to be 1.002487, a 0.0014% difference from the accepted value of 1.000263. The precision of this measurement is about ± 0.000001 based on partial derivatives of the variables, but probably isn't meaningful since the precision of some of the measurements used (such as the vacuum cell length) isn't known. The most important sources of error likely arose from (i) imprecise matching of the exact phase when counting patterns; (ii) disturbances of the table and vacuum cell positions; (iii) imprecise assumptions of cell size and air pressure; and (iv) slight effects from the glass surface of the cell and imperfections thereon. For example, using the true station pressure of $30.16'' Hg$[1] instead of assuming a standard pressure yields a more accurate value of 1.0002507 for n. A better result could also have been obtained with more trials in the initial wavelength measurement.

[1] Using ICAO Std. Aviation Wx. Data MONTREAL/DORVAL, QC (45.47,-73.75) 118 ft; 21-Oct-2002: METAR CYUL 211900Z 30005KT 30SM BKN057 05/M05 A3016 RMK SC7 SLP214=

initial position ($\pm 0.05mm$)	**final position** ($\pm 0.1mm$)	**displacement** ($\pm 0.1mm$)	$\lambda = \frac{2d}{50}$ ($\pm 4nm$)
100.0	115.9	15.9	636
100.0	116.0	16.0	640
100.0	115.9	15.9	636
100.0	115.7	15.7	628
100.0	115.8	15.8	632
		sum:	3172
		average:	634.4
		percent error:	0.252844501

Table 1: Part 1 data.

number of fringes, N	**pressure,** P ($cmHg$)	ΔP ($cmHg$)	ΔPN ($cmHg$)	$\Delta P2$ ($cmHg^2$)	$(N - \left(\frac{N}{\Delta P}\right) \Delta P)^2$
0	10.0	0.0			
4	22.1	12.1	48.400	146.410	0.064930
6	29.8	19.8	118.800	392.040	0.016509
8	36.0	26.0	208.000	676.000	0.002257
10	42.1	32.1	321.000	1030.410	0.004150
12	48.3	38.3	459.600	1466.890	0.021141
14	55.2	45.2	632.800	2043.040	0.000094
16	62.1	52.1	833.600	2714.410	0.015868
18	68.2	58.2	1047.600	3387.240	0.000197
		sums:	3669.800	11856.440	0.125147

Table 2: Part 2 data.

$\frac{N}{\Delta P}$ ($cmHg^{-1}$)	0.309519552
$\sigma_{\frac{N}{\Delta P}}$ ($cmHg^{-1}$)	0.0012279604
$n = \frac{N}{\Delta P}\lambda\frac{P}{2}l + 1$	1.000248722
accepted n	1.000263
percent error	0.001427459

Table 3: Conclusion.

A Sample Calculations and Error Analysis

A.1 Part 1

Calculating the displacement:

$$\begin{aligned} displacement &= final - initial \\ &= 115.9\mu m - 100.00\mu m \\ &= 15.9\mu m \end{aligned}$$

Calculating λ:

$$\begin{aligned} \lambda &= \frac{2 \cdot displacement}{N} \\ &= \frac{2 \cdot 15.9\mu m}{50} \cdot \frac{1000nm}{1\mu m} \\ &= 636nm \end{aligned}$$

Error on λ:

$$\begin{aligned} \sigma_\lambda &= \sqrt{\sigma_{pi}^2 + \sigma_{pf}^2}\frac{2}{50} \\ &= \sqrt{(0.05\mu m)^2 + (0.1\mu m)^2}\frac{2}{50}\left(\frac{100nm}{\mu m}\right) \\ &= 4nm \end{aligned}$$

Calculating average λ (note that the error is the same on each λ, therefore weighted average is not necessary:)

$$\begin{aligned} \lambda_{ave} &= \frac{1}{K}\sum_{i=1}^{K}\lambda_i \\ &= \frac{1}{5} \cdot (636nm + 640nm + 636nm + 628nm + 632nm) \\ &= 634.4nm \end{aligned}$$

Percent error between λ_{ave} and accepted λ:

$$\begin{aligned} p &= \frac{|\lambda_{average} - \lambda_{accepted}|}{\lambda_{accepted}} \cdot 100\% \\ &= \frac{|634.4nm - 632.8nm|}{632.8nm} \cdot 100\% \\ &= 0.25\% \end{aligned}$$

A.2 Part 2

Calculating ΔP:

$$
\begin{aligned}
\Delta P &= final - initial \\
&= 22.1cmHg - 10.0cmHg \\
&= 12.1cmHg
\end{aligned}
$$

Calculating the slope of the plot N it vs ΔP:

$$
\begin{aligned}
\frac{N}{\Delta P} &= \frac{\sum \Delta P N}{\sum \Delta P^2} \\
&= \frac{(3669.8cmHg)}{(11856.4cmHg)^2} \\
&= (0.3095cmHg)^{-1}
\end{aligned}
$$

To calculate the error on the slope:

$$
\begin{aligned}
\sigma_{\frac{N}{\Delta P}} &= \sqrt{\frac{\frac{1}{N-1}\sum_{i=1}^{N}\left(N - \frac{N}{\Delta P}\Delta P\right)^2}{\sum \Delta P^2}} \\
&= \sqrt{\frac{\frac{1}{8-1}\left(\left(4-(0.3095cmHg)^{-1}(12.1cmHg)\right)^2 + ... + \left(18-(0.3095cmHg)^{-1}(58.2cmHg)\right)^2\right)}{(12.1cmHg)^2 + ... + (52.8cmHg)^2}} \\
&= (0.001228cmHg)^{-1}
\end{aligned}
$$

(see part 1 for sample percent error calculation.)