

# Lab report for PHYS 4211

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## Abstract

We describe some experiment where we used an oscilloscope and tweezers to measure something or other. This demonstrated the equivalence of confusion with befuddlememnt and allowed us to measure  $\hbar$  to a precision of  $\pm 3$  km.

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## 1 Introduction

2 This piece is the introduction. It should place the experiment in some sort of  
3 general context so that the reader knows why the experiment was performed.  
4 Strive to describe the big picture. It is ok to cite other experiments[1] that  
5 may be relevant. You can also use equations like  $I = I_0 \exp(-x/\mu(\lambda))$ . Here,  
6  $I/I_0$  is the relative light intensity at wavelength  $\lambda$  measured at position  $x$  for  
7 light produced at  $x = 0$ .

8 Previous schemes for measuring  $\mu(\lambda)$  in mineral oil have emphasized a fully  
9 manual approach. For example[2][3], light from an LED can be collimated,  
10 focussed and filtered to produce a quasi-monochromatic pencil beam which is  
11 directed along a vertical, liquid-filled tube to a photodetector at the tube's far

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12 end where the light intensity is measured. Manually filling/draining the tube  
13 and measuring the fluid column length is then combined with the associated  
14 light intensity to yield  $\mu$ . Although straightforward to implement, such manual  
15 procedures tend to be both time consuming and susceptible to systematic error  
16 from the potentially large number of human interactions required for extensive  
17 sampling. The procedure described in this article substitutes an electronic  
18 technique for the manual filling/draining and fluid column measurement and  
19 was developed for the electron neutrino appearance experiment NO $\nu$ A[4] at  
20 Fermilab as part of a suite of testing techniques for ensuring the quality of the  
21 experiment's 16 million liters of liquid scintillator.

## 22 **2 Two column spectrophotometer**

23 Our technique relies on a two column spectrophotometer, with both vertical  
24 columns filled with the mineral oil to be tested and supplied in parallel by  
25 a vertically adjustable oil reservoir. The "optical column" has filtered and  
26 focussed light directed along its length to a photomultiplier (PMT) at its far  
27 end. The parallel plumbed "capacitive" column has its capacitance, related to  
28 the length of it filled with oil, measured electronically. Detected light intensity  
29 as a function of fluid column length yields the oil's  $\mu(\lambda)$ .

30 The structure of the optical column is conventional. A blue LED, pinhole, con-  
31 verging lens and narrow bandpass filter are positioned axially at the top of the  
32 5 cm diameter aluminum alloy tube. The filtered LED light is collimated and  
33 focussed to produce a  $\sim 3$  cm diameter spot size in a horizontal plane at the  
34 end of the tube 1.2 meters away. The tube bottom is sealed with a borosilicate  
35 window, against which a 51 mm diameter PMT is placed. The PMT photo-

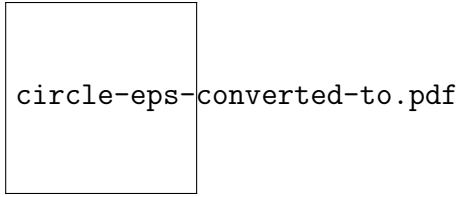


Fig. 1. Schematic of two-column spectrophotometer, showing the reservoir, optics column and capacitive column.

36 cathode is biased at negative high voltage and the photocurrent is readout in  
37 DC mode by a simple op-amp circuit configured as a transimpedance amplifier  
38 with a 600 k $\Omega$  resistor in the feedback loop. The optical tube is sealed against  
39 light and a stainless steel valve installed at the tube bottom aids oil draining  
40 when changing oil samples.

41 The aluminum alloy capacitor tube is a pair of 1.0 m long concentric tubes with  
42 annular radii 1.5 cm and 2.5 cm. It is open to the atmosphere at the top but  
43 sealed at the bottom with a PVC disk. Oil is admitted to the volume between  
44 the individual tubes through a fitting attached to a 1 cm diameter hole drilled  
45 in the outer diameter tube. Opaque polysomething tubing of diameter 1 cm  
46 connects the capacitor tube to both the optics tube and the oil reservoir. See  
47 Figure 1 for a schematic of the arrangement.

48 A 4 liter oil reservoir supplies both the optics and capacitor tube through a  
49 “tee” connection so that all three can be placed in hydrostatic equilibrium  
50 with one another. The reservoir is attached to stage driven by a stepper  
51 motor, permitting the vertical level of the fluid in the optics and capacitor  
52 tube to vary by  $\sim 80$  cm. The nominal step size  $d$  of the motor controller in  
53 combination with the stepper lead screw is  $\sim 0.1$  mm.

### 54 **3 Math equations**

55 You may need to write an equation, or two. You already have seen how to write  
56 one inside a paragraph: you just type the latex math command sandwiched  
57 between \$ signs:  $\int_0^\infty e^{-x} = 1$ . You write an equation all by its lonesome and  
58 **without** equation numbers:

$$59 \quad e^{i\pi} + 1 = 0.$$

60 or with equation numnbers:

$$61 \quad e^{i\pi} + 1 = 0 \tag{1}$$

62 You can now refer to formula 1 in your text. The command

63 `\label{eq:euler}`

64 in the source code just attaches a label to the formaula that allows you to  
65 reference it. this is a handy trick.

### 66 **4 Conclusion**

67 Finish what you start.

### 68 **References**

69 [1] Borexino, Daya bay, Double Chooz, miniBOONE, NO $\nu$ A.

70 [2] J.L. Raaf et al., *IEEE Trans. Nucl. Sci.* 49 (2002) 957.

<sup>71</sup> [3] J.P. Petrakis et al., *Nucl. Instr. Meth. A* 268 (1988) 256.

<sup>72</sup> [4] J.H. Christ et al., *Some Journal* 123 (2007) 1.