# *Physics 205L* Final exam

January 17, 2008

**Name:_____**

**Section number:_____**

**Instructor's Name:_____**

**ID number:_____**

DO NOT START THE EXAM BEFORE YOU ARE TOLD TO BEGIN

Grading

| | |
|---|---|
| **I** | |
| **II-1** | |
| **II-2** | |
| **II-3** | |
| **TOTAL** | |

***The duration of this exam is 60 minutes.***

***No notes or books allowed.***

***Scientific calculators are allowed***

***All results should be given with the exact number of significant figures.***

**I.** **(55%)** The dielectric constant *k* of the material that fills the space between the two conductors of a coaxial cable is to be determined. Cables of different outer diameters *b* were used and the capacitance of each was measured. All cables have an inner diameter of $a$ = 0.037 cm and a length $L$ = 1 +/- 0.001 m. The permittivity of free space is $\varepsilon_0 = 8.85 \times 10^{-12} C^2 / Nm^2$
The results below were obtained:

| *b* [cm] | *C*(pF) | | | | |
|---|---|---|---|---|---|
| 0.110 | 102.10 | | | | |
| 0.231 | 60.72 | | | | |
| 0.320 | 51.55 | | | | |
| 0.415 | 46.01 | | | | |
| 0.517 | 42.17 | | | | |
| | | | | | |

*You may find the formulae on page 5 useful.*

a- Write down the necessary relation between *C* and *b*.

b- Choose your variables *x* and *y* such that you obtain a linear relationship between them.

c- Use linear regression to find the slope of the line along with its error.

d- Determine the dielectric constant *k* along with its error.

# Linear Regression

The *method of least squares* is used to fit a curve (find a theoretical equation) to a set of experimental data. First assume that a linear relation exists between y and x

$$y = Ax + B \tag{1}$$

Substitution of $x = x_i$ will in general not give the value of $y_i$. The "errors" will be

$$e_i = y - y_i = Ax_i + B - y_i \tag{2}$$

To determine the best straight line that fits the N, sets of data, A and B have to be chosen so that the sum of the squares of the "errors" is minimized. This means that the simultaneous equations, obtained by equating the partial derivatives of $(y - y_i)^2$ with respect to A and B to zero, should be solved. This condition leads then to the following results

$$A = \frac{N\sum(x_i y_i) - \sum x_i \sum y_i}{\Delta} \tag{3}$$

and

$$B = \frac{\sum x_i^2 \sum y_i - \sum x_i \sum (x_i y_i)}{\Delta} \tag{4}$$

where

$$\Delta = N\sum x_i^2 - (\sum x_i)^2 \tag{5}$$

The *correlation coefficient r* provides an indicator of how good a fit the best straight line is. This coefficient is defined as

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} \tag{6}$$

For $r = 0$, the values of x and y are independent of one another and there is no linear correlation. The closer $r$ is to +1 or to –1, the better the linear correlation is.
Finally, the error in A is given by:

$$\sigma_A^2 = \frac{N}{N-2}\frac{\sum e_i^2}{\Delta}$$

## II. Questions

**1.** In the "Planck's Constant Experiment" **(15%)**

a- We used the equation $V_S = (\frac{h}{e}) f - \frac{\phi}{e}$ in order to determine h and $\phi$. Explain how.(10%)

b- Define the photoelectric effect. (5%)

**2.** In the e/m experiment, why did we tilt the Helmholtz coils and kept them at that orientation throughout the experiment? **(10%)**

**3.** In “Ohm’s Law” experiment, explain how the resistivity of metal rods were determined. Include necessary equations. **(20%)**