Introduction to Laboratory

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PREFACE

We will assume that the student’s skill level has improved significantly since the Phys 225L course. Here we add comments on the consequences of mistakes in the lab, new hazards and statistics.

Consequences of Mistakes:

There are 3 types of mistakes a student can make in the lab; those that could result in harm to others, those that damage equipment, and those that harm the student. These get dealt with in different ways.

- The minimum penalty for endangering another person will be expulsion from the lab, resulting in no credit for the lab.
- The cost of repairing malicious damage to the equipment will be charged to the student. The instructor will decide on a case-by-case basis whether or not to allow the student to complete the lab.
- Some damage to the equipment is the inevitable result of use. It must be reported immediately to the instructor so repair can be made, but there is no penalty for such damage.
- Harm to the student is usually considered to be the unfortunate result of not following instructions or asking for clarification.
New Hazards:
The new equipment in this course consists of lasers and associated optical apparatus and some radioactive materials. Here are the rules for dealing with these;

- DO NOT shine a laser beam into the eyes, either directly or from a mirror or grating.
- DO NOT look into the laser beam at any time.
- DO NOT touch the surface of optical elements, mirrors, lenses and gratings
- DO NOT touch bare electrodes when the power supply is plugged in or otherwise charged.

Calculation of Errors:
This is a very basic theory to be applied in experiments, so that results can be quoted with a plus/minus error.

For a full description of error analysis the student should look at a text on the subject such as, “Errors of Observation and their treatment”, by J. Topping, Science Paperbacks 1972.

Collecting data $x$ and finding a mean result $x_0$ and standard deviation $\sigma_x = \delta x$. The final result should be quoted as;

$$ X = x_0 \pm 2\sigma_x \quad \text{The ranges should miss the true result only 5\% of the time.} $$

The mean of a set of data with $N$ data points is;

$$ x_0 = \frac{1}{N} \sum_{i=1}^{N} x_i $$

The standard deviation of the same set of data $\sigma_x$ is given by;

$$ \sigma_x = \left[ \frac{1}{N-1} \sum_{i=1}^{N} (x_0 - x_i)^2 \right]^{1/2} $$

Use of Calculus:
Calculus can be used for estimation of errors. Suppose you measure $x$, and substitute into a formula $y = f(x)$.

If $\delta x$ is the error in $x$ then the corresponding error in $y$ will be approximately, $\delta y = (dy/dx) \delta x$.

Suppose $y$ is the area of a circle and you are measuring the radius $x$, with error $\delta x$. Then

$$ y = \pi x^2, \quad dy/dx = 2 \pi x \quad \text{and hence the error in } y \text{ is,} \quad \delta y = 2 \pi x \delta x.$$
The fractional error in $y$ is

$$\frac{\delta y}{y} \cong \frac{2 \pi x \delta x}{\pi x^2} = \frac{2 \delta x}{x}$$

If the measured quantity is a function of several measured variables then you may use the

**principle of superposition of errors**, which can be explained as follows;

If $R$ is a function of $x$, $y$, $z$ with measured errors $\delta x$, $\delta y$, $\delta z$, then if the values are correlated, the total error in $R$ is given by $\delta R$

$$\delta R = \frac{\partial R}{\partial x} \delta x + \frac{\partial R}{\partial y} \delta y + \frac{\partial R}{\partial z} \delta z$$

However, if $x$, $y$, and $z$ are independent of each other, then the most probable value of $\delta R$

is given by

$$\delta R = \sqrt{\left(\frac{\partial R}{\partial x} \delta x\right)^2 + \left(\frac{\partial R}{\partial y} \delta y\right)^2 + \left(\frac{\partial R}{\partial z} \delta z\right)^2}$$

which is the sum of the squares of the greatest errors due to each variable separately.

You may then define your answer as $R = R_0 \pm 2 \delta R$ where $R_0$ is your average value of $R$.

(Note it is implied that $\sigma_R = \delta R$).

There are many variations on the error theme and these can be looked up for advanced laboratories in the Topping book referenced above.