LABORATORY INFORMATION

Welcome to the laboratory section that accompanies your physics lecture course at Saddleback College. Experiences in the lab are designed to meet a variety of objectives. The lab allows each student to become more familiar with the concepts discussed in lecture through hands-on activities. The lab also gives students valuable job skills in the areas of data analysis, manipulation, recording and collaboration. There is emphasis on communication of ideas in written and graphical form, along with the development of teamwork skills. There are no make-up labs! It is strongly recommended that you participate and attend ALL of the laboratory exercises as they reinforce lecture concepts, there will be questions on the mid-term/final-exam related to laboratory and you will loose participation points (see ***Syllabus***) when not in attendance.

Lab Notebook Instructions:

Place 50 – 100 sheets of graph or notebook paper at the end of notebook and the blank ***Informal Lab Reports*** (printed in ***First Assignment***). Place ***Lab Notebook Table of Contents*** (printed in ***First Assignment***) at beginning of lab notebook then the ***Laboratory Information*** sheet (printed in ***First Assignment***) followed by the *Sample Formal for Density of a Metal Cylinder* and the corresponding lab instructions with the informal/formal reports for each lab. Please either number all of the pages in the notebook and fill in the table of contents OR systematically identify each ***Informal Lab Report*** with a titled tab (on the right-hand side) so that your professor can quickly access your labs.

Lab Report Guidelines

(See Syllabus for instructions on assembling Lab Notebook.)

Most lab experiments are available for download on the course website (see ***Syllabus***). It is the student's responsibility to download, print, **and read** the lab experiments **prior to lab** in addition to **completing a *Pre-lab*** (see *Informal Report* below)**.** IF YOU DO NOT HAVE A PRINTED COPY OF THE LABORATORY EXPERIMENT FOR THAT DAY'S LAB, YOU WILL NOT BE ALLOWED TO PARTICIPATE IN THE LAB.

INFORMAL REPORTS:

Ten to thirteen informal labs will be completed (one informal lab with error propagation, Range of a Projectile) throughout the semester. An informal lab will be completed for every lab experiment (including those for which a formal lab is completed). ALL informal labs will be hand written! **Pre-labs** are due when you first walk in to lab and consist of the student reading the lab then completing (in their own words) the following sections of the ***Informal Lab Report*** sheet: *Title, Name, Purpose, Theory* (see bullets below for details).

The ***Informal Lab Report*** is due at the end of the three-hour lab period (unless an extension is given to the entire class or just your lab team, in which case the informal lab is due at the beginning of the following class session.) **Otherwise, no late *Informal Lab Reports* will be accepted.** Your **informal reports** will include the completion of the ***Informal Lab Report*** sheet which contains areas such as *Purpose, Theory*, etc. the details of which are expanded upon in several of the bullets below.

GRADING CRITERIA (Note: **BONUS points** are **QUIZ** points.):
Informal Lab Write-Ups:

- **Exceptional** quality then up to **+2 BONUS points** received (~3 % potential grade increase)
- **Acceptable** quality then **0 BONUS points** received
- **Unacceptable** quality, a **missed lab** and/or **no informal lab turned in** then up to **– 20 BONUS pts** (~25 % potential grade decrease, near failure)
- ➢ The one informal lab with the lowest associated **BONUS points** will be **dropped.**

FORMAL REPORTS:

There will be **three** formal labs completed (one with error propagation and two without) worth 40 lab points each. Formal laboratory reports must be **typeset** using **computer word processing** and **spreadsheet software**. You must use software such as **Equation Editor** (remind me to show you how to access this) to type equations and draw any graphs using software such as Excel. There are campus computer labs available for your convenience both on the 3rd floor of the Science Math building and in the library or arrangements can be made for you to use the computers in the laboratory for typing formal reports.

Make sure that you **check** the **spelling** and **grammar** in your formal report. The formal report must be in your own words. Although you complete the lab as part of a team, each individual turns in a separate & unique lab report. **No part of your formal report can be the same as another person's formal report.** If material is used from a source other than you, make sure that a reference is given. See the MSE ***Academic Integrity Policy.*** A formal lab report can be no more than 2-weeks late and one letter grade is deducted (i.e. formal 4 pts/week) for each week it is late.

Your **formal reports** must include the following information **in the given** order:

- **Title of Experiment:** (Each **formal report** should have a **cover page**, which indicates the title of the experiment, the members of the lab team, the date that the experiment was performed and the scheduled lab meeting day and time for the team. Following this cover page is the actual lab report.)
- **Your name** (skip for formal report since on cover page)
- **Lab partner(s) name(s)** (skip for formal report since on cover page)
- **Purpose:** Write in your own words, the objective of the lab experiment, i.e. what physical principles or phenomenon are you here to investigate? (What is it that you are trying to accomplish?)
- **Sketch:** All sketches for **formal reports** must be either drawn with a computer drawing program or have a photo/drawing from the web or a digital camera (swiping the digital photo from the lab, does not count).
- **Equipment:** A list of equipment used during the experiment for an informal, this may be cut and pasted from lab experiment)
- **Theory:** Write in your own words, the relevant principles, theories and equations used in the experiment go here. These should appear in sentence and mathematical form. Make sure that any principles and equations used for analysis are introduced here. Don't forget error propagation equations! Also, make sure that all symbols/variables are clearly defined for the reader. Any relevant derivations should be shown here as well (especially PH 4A, 4B & 4C).
- **Procedure:** A step by step listing (i.e. list vertically as step 1, 2, 3, etc) of the procedure you followed to complete the experiment. The **procedure must be in your own words** and must be **reproducible**. **Do not copy from the lab manual.** This listing should be entered in the Laboratory Notebook either before you perform the experiment or while you are performing the experiment. Do not wait until you have completed an experiment and analysis to start writing the steps of your procedure in your lab notebook. You may forget some things that were necessary to complete the experiment.
- **Data:** The data that you collect during an experiment goes here. Keep close track of your significant figures. It should be in ***tabular form whenever possible***. A computer generated table must be used for data in a formal lab write-up. As data is collected in an experiment, record that data in your lab book by hand. **DO NOT ERASE "DATA" in the lab book**, instead draw a single line through the error, then record the correct information. In this way, if an error is made concerning the validity of a piece of information, that information has not been destroyed. Do not wait for a fancy printout of your data, as information can be lost forever if it is mistyped into a computer. Remember to include estimates of your uncertainty or random error in your measurements (if doing error propagation).
- **Analysis/Calculations and Graphs:** For each type of computation performed during the experiment, provide one sample calculation. This includes calculations performed by a spreadsheet. You do not need to repeat every computation in your data book, but you should include one to check that everything is going smoothly. Remember to pay attention to significant figures and units in the sample calculations.

  When asked to provide a **graph** (usually completed on Excel), glue or tape the computer generated graph into your data book and/or formal report and, immediately after the graph. Remember to title your graphs and label the axes. Include units with your axis labels and, as always, watch those significant figures on your axes.

If a handbook (i.e. theoretical) value exists for the quantity you are experimentally measuring, compare your experimental value to the handbook value by performing a percent difference calculation. Use the following percent difference formula:

$$\%difference = \frac{\left|THEORETICAL_{value} - EXPERIMENTAL_{value}\right|}{THEORETICAL_{value}} \times 100$$

For labs involving error propagation, show your error propagation calculations here as well. (Your instructor will give you more details on this later.)

- **Conclusion:** Finally, conclude your work. Conclusions are based on the data collected and supported by the results of the analysis. Include the following items in your conclusion:

1. Discuss to what extent the purpose/objective of the experiment was realized. Every experiment has a purpose/objective. Given your observations, the data collected in the lab and the results of the analysis, did you meet your objective?
2. Restate your experimental value(s). If doing error propagation, restate the percent error(s) {i.e. the uncertainty} associated with this value(s***).*** If a theoretical/accepted value exists, state the theoretical value(s) and the percent difference(s) between the experimental and theoretical values.
3. ***When using error propagation:*** *If the percent difference is not larger than the percent error in the experimental result/value as determined by error propagation, then we have taken into consideration most of the significant sources of error and there is agreement between the theoretical value and the experimental value. Discuss whether there is agreement between the theoretical value and the experimental value. Some sources of error may be present which may not have been taken into consideration and some reasonable explanation of why there was not agreement should be included in the lab report/write-up.*
4. Briefly discuss at least 2 or 3 possible sources of error leading to the uncertainty in your experimental value. BE CAREFUL YOU DO NOT MISS the MOST SIGNIFICANT SOURCE(S) OF ERROR. Simply stating “measurement error” and/or “human error” is not specific enough. Instead specifically describe the instruments, measurements, etc. that could account for your error (e.g. parallax error, air-resistance, friction in a pulley, the mass of a string).
5. Answer any questions in the laboratory exercise.
6. OPTIONAL: If you have any suggestions for improving or changing the lab, please volunteer them here.
7. Finally, sign and date the lab book and/or formal report. This is your stamp of approval indicating you certify the work done.

Types of Experimental Errors & Estimating Random Errors

Experimental errors generally can be classified into three types: Personal, systematic, and random.

<u>Personal Error</u>

These errors arise from personal bias or carelessness in reading an instrument, in recording data, or in calculation, and in parallax in reading a meter. **Of these, only parallax errors can be estimated and used in error propagation**. Effort should be made to eliminate personal errors.

(When looking at a non-digital meter, there is a small distance between the needle and the scale. As a result, the reading will change as the observer's eye position changes from side to side. This apparent change in position is called parallax.)

<u>Systematic Errors</u>

Errors of this type result in measured values which are consistently too high or too low. Conditions, which lead to systematic errors, are as follows:

1. An improperly calibrated instrument such as a thermometer, which consistently reads 99 degrees Celsius in boiling water instead of 100 degrees Celsius.
2. A meter which was not properly zeroed. An example would be an ammeter or voltmeter.
3. Theoretical errors due to using a simplified mathematical model for the system which consistently gives a calculated value different from the calculated value predicted from a more accurate model.

In principle, systematic errors can and should be eliminated.

<u>Random Errors</u>

Random errors result from unknown and unpredictable variations in experimental measurements. Possible sources of random errors are:

1. Observational – e.g. errors when reading the scale of a measuring device to the smallest division.
2. Environmental – unpredictable fluctuations in temperature, line voltage, or other parameters beyond the experimenters control.

<u>Estimating Random Errors</u>: Random errors can be determined statistically when there are many measurements of the same quantity. We will see and use the statistical methods for analysis in Lab #1, but for the remaining lab experiments we will use an easier method which does not require the time nor the resources necessary when using statistical analysis. This easier method which is usually adequate, utilizes the precision of the instrument and the judgement of the experimenter.

The error in a given instrument reading is determined from taking an estimated reading between the smallest division on that instrument. The smallest division on an instrument is called the ***least count*** and any reading smaller than the ***least count*** is an estimated reading. For example, a measurement on a meter stick may be 86.35 cm. Since the meter stick has 0.1 cm as the smallest division, the rightmost digit is estimated and thus is doubtful (i.e. the 0.05 cm is estimated in the measurement of 86.35 cm). Therefore, the experimenter must estimate the error in the rightmost digit. In many measurements, the smallest division represents the rightmost digit in the value of that measurement and the error in the measurement is $\pm$ the ***least count***.

Some measurements have an error larger than the least count and the experimenter again must estimate the amount of error. An example illustrating the judgement of the experimenter would be measuring the distance between the two spots shown below which may represent the reflected beam from a laser used to determine small rotations of a mirror. The center of each spot must be estimated and the error is likely to be more than the least count. Measure the distance between the spots using a ruler having a least count of 0.1 cm.

The random error (uncertainty) in an experiment may be expressed as an absolute error or as a percent error. Absolute error is of the form $\pm \ \delta x$ where *x* is a measured value and the experimenter estimates $\pm \ \delta x$. In judging the significance of the absolute error/uncertainty (i.e. $\pm \ \delta x$) in comparison with the measured value of *x*, the ratio $\delta x / x$ is the more useful quantity. This ratio, usually expressed as a percentage, is referred to as "percent error/uncertainty" and tells us about the precision of our measurement.