PHYS 275 – Experiment 1

Course Personnel

- Instructor: Alberto Belloni
  - PSC 3208F (office suite in front of elevators)
  - abelloni@umd.edu
  - 5-6058
  - Office hours: stop by my office, but make appointment to make sure I will be there!
- Teaching Assistant: Dan Zhang
  - PHY 3103B (Toll building)
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Course Description

- Experiments mainly chosen in area of mechanics
  - Statistics, free fall, standing waves…
  - Theory and application of uncertainty analysis is one goal of class
- Syllabus available on ELMS
  - Please read it; it contains important information about the course organization, grading…
- Texts
  - Required: laboratory manual, available on Expert-TA
  - Optional: “A practical guide to data analysis for physical science students”, L. Lyons

Online Resources - Expert-TA

- Please register to Expert-TA as soon as possible
  - 301 Link: http://goeta.link/USH22MD-4A98E0-1L1
  - 401 Link: http://goeta.link/USH22MD-B62CFF-1L0
  - Register and complete fee payment
- Exper-TA provides:
  - Access to electronic copy of laboratory manual
  - Automatic grading of homework sets

Homework Grading Schema

Grade Preferences for the Following question types: Equations, Numeric, Multiple Select

Students are allowed to access Hints?	(•) Yes ( ) No
Deduction for each accessed Hint	0 (% of part value) Range: 0 to 100
Number of allowed Submission Attempts	3 (number of attempts) Range: 1 to 20
Deduction for each Incorrect Submission Attempt	0 (% of part value) Range: 0 to 100
Students are allowed to access Feedback?	(•) Yes ( ) No
Deduction for each accessed Feedback	0 (% of part value) Range: 0 to 100
Feedback Style	(•) Socratic ( ) Direct
Students are allowed to access the Correct Answer?	(•) Yes ( ) No
Deduction for accessing Correct Answer	100 (% of part value) Range: 0 to 100
Max. % for Late Work	50 (% of part value) Range: 0 to 100
Randomize Variables?	(•) Yes ( ) No
Randomize Phrases?	( ) Yes (•) No

A practice assignment is available
Please do it to get familiar with Expert-TA

Grade Schema for Multiple Choice

For multiple choice questions (where N choices are available), the number of attempts students are given is the number of choices minus one (N-1). The deduction for each incorrect submission is equal to %deduction = 100/(N-1).

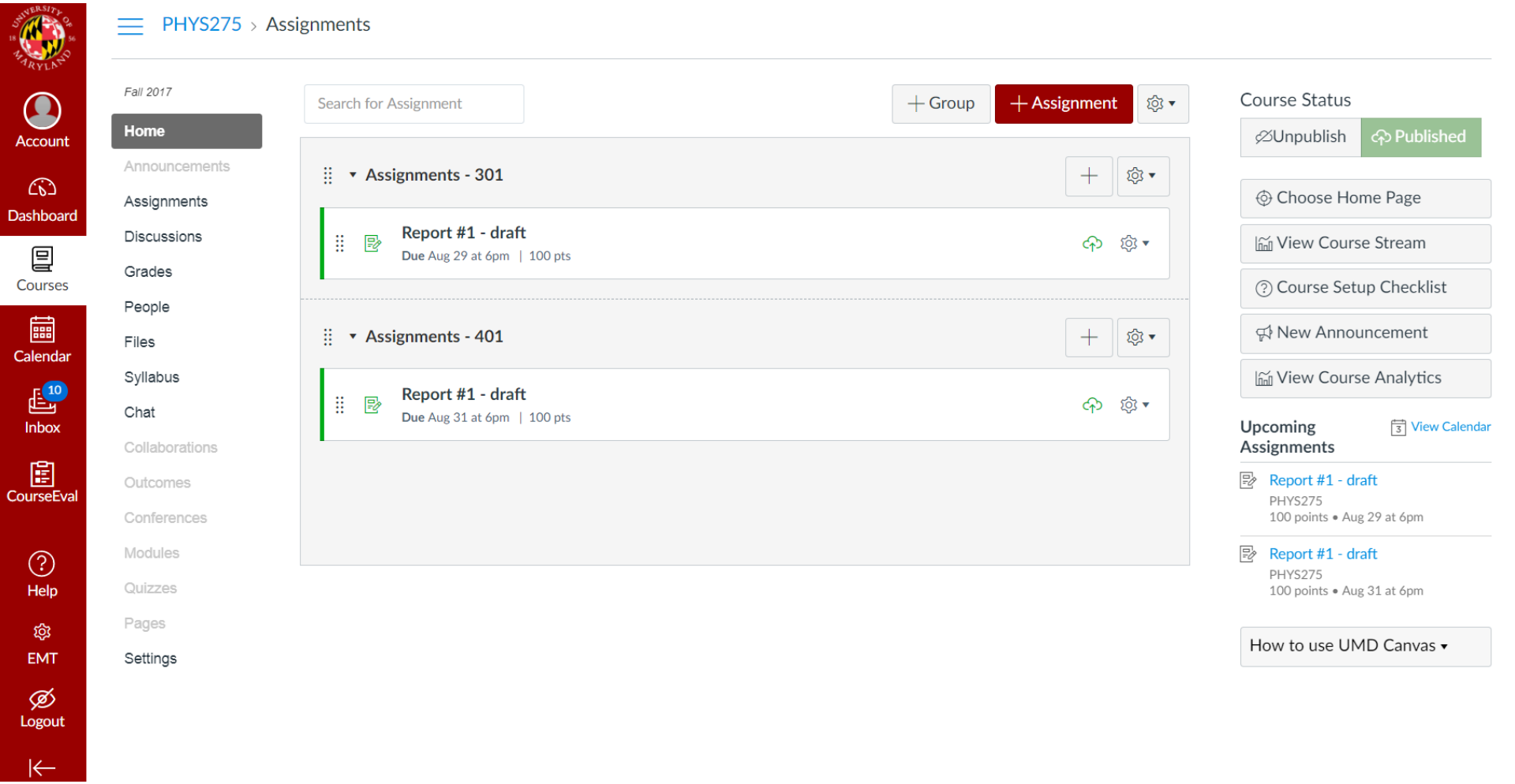
Note: If the deduction for incorrect submissions in the table above is equal to 0, the deduction amount for multple choice incorrect submissions will also be set to 0. In this case the number of submission attemtps is also changed and is equal to the 'Number of Allowed Submission Attempts' specified in the table above.

Grade Schema for True/False

For True/False questions students are given one attempt and deduction amount for an incorrect answer is 100%.

Note: If the deduction for incorrect submissions in the table above is equal to 0, the deduction amount for true/false incorrect submissions will also be set to 0. In this case the number of submission attemtps is also changed and is equal to 2.

Online Resources - ELMS



Online Resources - ELMS

- Copy of the syllabus
- Calendar with assignments
- Assignments (and grades)
  - At the end of each laboratory, you need to submit a spreadsheet with your measurements
    - This counts as your DRAFT report
  - By 1pm, one week after the lab, you may post on ELMS a revised / completed version of the report
    - This counts as your FINAL report
  - We will grade the FINAL report, but if you are happy with the draft, we will grade the draft
    - No penalty for not posting a final report
- By next week, a detailed guideline about the laboratory report format will be posted on ELMS

Course Requirements

- Be in lab on time
  - Will start lab with a ~20-min introduction
- Read over and think about the lab before coming to class
- Remember to submit electronically a copy of your Excel spreadsheet to the ELMS course site *before* leaving lab
  - This is your DRAFT report
- Turn in your check-sheet *before* leaving lab
- Submit your *final* revision of lab report by 1pm in the following week
  - No penalty if you do not: we will grade the draft report
- Finish up homework by 2pm in the following week
  - The homework is available on Expert-TA
- Treat all the experimental setup with care
- **No drink and food in the lab!**
- SAFETY FIRST
  - First: people; second: equipment!

Grading Details

- Grading schema
  - 40% : Spreadsheet Lab Report
  - 10% : Homework
  - 25% : Midterm (Practical Exam1)
  - 25% : Final (Practical Exam 2)
- Missing one lab (and not making it up): one letter grade in your final grade
  - Please let us know as soon as possible if you cannot attend a lab, we will try to organize a make-up session
- Missing one homework set: one-half of a letter grade in your final grade
  - Homework is assigned through Expert TA at the end of each Lab. You will complete your homework online (will be graded automatically by Expert TA)
- No credit will be given for late homework unless you are seriously ill and provide a written note from your physician

- Since this is the first time that we use Expert TA, if you notice any issue when using Expert TA or if you believe your homework is graded incorrectly please let us know immediately

Calendar

Date	Experiment
Aug 28-Sep 1	1 – Diagnostic experiment
Sep 4-8	No labs – Labor Day
Sep 11-15	2 – Of dice and distributions
Sep 18-22	3 – Statistics of random decay
Sep 25-29	4 – Position, velocity, and acceleration
Oct 2-6	5 – Free fall of a mass
Oct 9-13	6 – First review (experiments 1-5)
Oct 16-20	**First Practical Exam**
Oct 23-27	8 – Standing waves on a string
Oct 30-Nov 3	10 – Forced harmonic motion
Nov 6-10	12 – Designing an experiment to measure *g* to 0.1%
Nov 13-17	13 – Second review (experiments 8, 10, 12)
Nov 20-24	No labs – Thanksgiving
Nov 27-Dec 1	**Second Practical Exam**

Significant Figures

- Capital rules
  - Any digit that is not zero is significant
  - Zero between non-zero digits are significant
  - Zero to the left of the first non-zero digit are not significant
  - For numbers with decimal points, trailing zero may or may not be significant. To indicate that trailing zeros are significant a decimal point must be added
- In general, the last significant figure in any result should be of the same order of magnitude, i.e., in the same decimal position as the uncertainty
- When doing calculations, it is good idea to keep one more digit than is significant to reduce rounding errors. But in the end, the answer must be expressed with only the proper number of significant figures
  - After addition or subtraction, the result is significant only to the place determined by the largest last significant place in the original numbers

Quick Example

0.00020900

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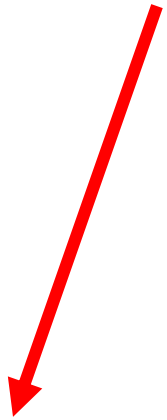
0.00020900



All nonzero digits and zero between non-zero digits are significant

Quick Example

0.00020900

Zeros are not significant after decimal before nonzero digits

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Zeros are not significant after decimal before nonzero digits

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Zeros after nonzero digits in a decimal are significant

What is uncertainty?

- "Error" (I prefer to use "uncertainty") has to do with uncertainty in measurements that cannot be avoided
  - If a measurement is repeated, the values obtained will differ and none of the results can be preferred over the others
- Although it is not possible to do anything about such uncertainty, it can be characterized
  - For example, the repeated measurements may cluster tightly together or they may spread widely. This pattern can be analyzed systematically
- What is a valid uncertainty?
  - The difference between the measurement and the accepted value which can be looked up in a handbook (e.g., the density of brass) can be taken as uncertainty?
  - The difference caused by such as reading a scale backwards, misunderstanding what you are doing or elbowing your lab partner measuring apparatus can be taken as uncertainty?

Uncertainty Types

- Random uncertainty
  - Fluctuates from one measurement to the next. It displaces measurements in a arbitrary direction whereas systematic errors displace measurements in a single direction
  - Possible reasons: lack of sensitivity; noise; statistic processes such as the roll of a dice
- Systematic uncertainty
  - Tends to shift all measurements in a systematic way so their mean value is displaced
    - Another typical feature of systematic uncertainty: all uncertainties among measurements are *correlated*
  - Possible reasons: ill calibration of equipment; consistently improper use of equipment; failure to properly account for some effects; or other external effects (temperature?)

Multiple Measurements

Suppose an experiment were measured many, say N, times to get:

$$x_1, x_2, x_3, \ldots, x_N$$

- **Mean Value:** $\bar{x}$

$$\bar{x} = \frac{x_1 + x_2 + \ldots + x_N}{N} = \frac{\sum_{i=1}^{N} x_i}{N}$$

- **Standard Deviation:** σ_x

$$\sigma_x = \sqrt{\frac{\sum_{i=1}^{N} (x_i - \bar{x})^2}{N-1}}$$

Uncertainty Propagation

Combining results of different experiments

$$(a_1,\sigma_1),(a_2,\sigma_2),\ldots,(a_N,\sigma_N)$$

$$a=\frac{\sum_i\left(a_i/\sigma_i^2\right)}{\sum_i\left(1/\sigma_i^2\right)} \quad \text{and} \quad \sigma=\frac{1}{\sqrt{\sum_i\left(1/\sigma_i^2\right)}}$$

*For $\sigma_1=\sigma_2=\bullet\bullet\bullet=\sigma_N=\sigma_0$

$$a=\frac{\sum_i(a_i)}{N} \quad \text{and} \quad \sigma=\frac{\sigma_0}{\sqrt{N}}$$

 N larger, σ smaller

Suppose there two *independent* measurements, A and B, and the final result is Z=F(A,B) for some function F:

$$\Delta Z=\sqrt{\left(\frac{\partial F}{\partial A}\right)^2(\Delta A)^2+\left(\frac{\partial F}{\partial B}\right)^2(\Delta B)^2}$$

Examples

	Function Z=F(A,B)	Relation between errors ΔZ, (ΔA, ΔB)
1	$Z = A + B$	$(\Delta Z)^2 = (\Delta A)^2 + (\Delta B)^2$
2	$Z = A - B$	$(\Delta Z)^2 = (\Delta A)^2 + (\Delta B)^2$
3	$Z = AB$	$\left(\frac{\Delta Z}{Z}\right)^2 = \left(\frac{\Delta A}{A}\right)^2 + \left(\frac{\Delta B}{B}\right)^2$
4	$Z = A/B$	$\left(\frac{\Delta Z}{Z}\right)^2 = \left(\frac{\Delta A}{A}\right)^2 + \left(\frac{\Delta B}{B}\right)^2$
5	$Z = A^n$	$\frac{(\Delta Z)}{Z} = n\frac{(\Delta A)}{A}$
6	$Z = \ln(A)$	$(\Delta Z) = \frac{\Delta A}{A}$
7	$Z = e^A$	$\frac{(\Delta Z)}{Z} = \Delta A$

χ^2 Test (1)

- Chi-square test is a statistical test used to compare observed data with data we would expect to obtain according to a specific hypothesis, for example, goodness to fit. It can tell you if the deviations (difference between observed and expected) are the result of chance, or are due to other factors.

- Chi-square is a type of probability distribution

$$\chi^2 = \sum_i \frac{(x_i - \bar{x})^2}{\sigma_i^2}$$

$$\begin{cases} P(x,\nu) = \left(1 \Big/ \left[\Gamma(\nu/2)(2)^{\nu/2}\right] \right)\left(x^{\nu/2-1}\right)\left(e^{-x/2}\right) & , x \geq 0 \\ P(x,\nu) = 0 & , x < 0 \end{cases}$$

$$where, \Gamma(\alpha) = \int_0^\infty y^{\alpha-1} e^{-y}\, dy$$

- Degree of freedom, ν :

ν is defined at any stage in a statistical calculation as the number of independent measurements minus the number of parameters calculated from these measurements.

ν =(# of data)-(# of fitting parameters from measurements)

χ^2 Test (2)

- Chi-square Test

♫ way1: Compare the χ^2 with ν directly ⟺ reduced $\chi^2 = \chi^2/\nu \sim 1$;

♫ way2: Probabilities for Chi-square, $P(\chi^2,\nu)$

The number of P is the probability of obtaining a value of difference as large as the observed value, if the measurement really did follow the assumed distribution. Thus, if $P(\chi^2,\nu)$ is ~50%, the observed and expected distribution are consistent; if it is too small or too large, they probably disagree.

Significance levels (how significant does something have to be considered significant?) : there are two "cut-off" points commonly used by statisticians are the so called 5% and the 1% significant level. In particular, if $P(\chi^2,\nu)$ is less than 5%, we say the disagreement is significant and rejected the assumed distribution at the 5% level. If it is less than 1%, the disagreement is called highly significant, and we rejected the assumed distribution at the 1% level.

Today's Activity (and Notes)

- The main goal of today's test is to give both you and me a feedback about your data analysis knowledge
  - The test covers skills you will use often this semester
  - Also useful to test ELMS submission
- It is a closed book test, but please do not worry about your score
  - I will give everyone full score, but do your best: it is important that we find immediately if there could be problems later on
- If you have difficulty in finishing this test please try to review what we cover today and Appendix A in lab manual before next lab!
  - You can find APPENDIX A (p112) of the electronic manual quite useful!

- No lab for next week because of Labor Day
  - Our next lab is Exp.2 in the week of Sep 11
- Please register and practice Expert-TA before then