

Physics 408 Laboratory Survival Guide: Rules and Guidelines

Welcome to Physics 408 Laboratory!

Below you will find the rules and guidelines for the lab, including the marking breakdown for each component you are expected to complete for each lab module (total of four modules). You will be expected to complete an outline, introductory questions and the lab write-up for each module.

Warning:

Because the course runs concurrently with the lab, you may be faced with learning and using completely new concepts in the lab BEFORE you have seen them in the course lecture. You may also be required to do calculations that you have little or no experience doing.

This situation is commonplace in research environments and industry (i.e. real life) - so this is a desirable difficulty that you will learn to overcome. To help you get through this trial-by-fire intact, pre-reading and resources are listed at the end of each lab.

Lab Overview:

You will have four lab modules this term. You will have two or three weeks to complete each lab module (this will be finalized in the first week of class).

Following are some general rules and procedures for the labs:

- Absolutely no food or drink is allowed in the lab. You may, however, eat out in the main hallway.
- You are required to complete all 4 experiments and associated lab reports to pass the course.
- You must pass the lab component of the course to pass the course.
- After completing a lab, your lab writeup is due at the beginning of the next lab period.
- You should buy two lab (yellow) notebooks at the bookstore. You will have one week to hand in your finished lab - due the next lab period after finishing that lab. While that notebook is being marked, you will use your second notebook for the next lab.
- You will work in groups of 2, and both partners must document separately all data and information. The schedules and the names of the section teams will be posted on the website.

Following is a general break down of what you should aim to complete during each lab period:

- At the beginning of the first lab period you will submit your outline for the current module and lab from the previous module. The only exception is the first week where you will only hand in an outline.
- In your first lab period you should focus on scanning through the lab and getting yourself familiar with the equipment. Do not feel like you need to be following the lab in the presented order, skip around the sections as you wish.
- In your second lab period, you should take some data and work through the identified difficult parts of the lab.
- In your final lab period, you should have attempted some of the analysis and be ready to retake any data that was not sufficient. Complete all necessary data and parts of the lab that require the use of the equipment.

Marking:

Outline - 10%

Introductory Questions - 10%

Lab - 80%

Late penalties (We will be very strict about these penalties and there will be no exceptions):

- Labs are **due** at the beginning (not even 5 minutes late) of YOUR lab section when you are starting a new lab module. That means you typically have three weeks from the start of a lab to when you submit your lab.
 - Labs **not** submitted at the beginning of YOUR lab section: **50% reduction**. You have ONE additional week to submit your lab without additional reduction. You can submit at any time during that week, so you can find time to complete the lab to your best ability.
- > 1 week late: The labs will **no** longer be accepted.

Outline

You will be expected to complete a **one** page outline due at the beginning (not even 5 minutes late) of YOUR lab section of the first week of a lab module.

Expectations:

You should print TWO copies of your outline, one to submit for comments and marks (this will be returned to you at the start of the second week of your module) and one to keep for use during the lab.

These outlines are designed to help you prepare for the lab and think about the experiments you will perform over the course of the module. It will also help you plan out how you will complete the lab in the given amount of time, what parts of the lab may be most challenging, and what data needs to be collected in the lab and what analysis can be done at home.

Outline Guideline:

- Must be ONE page
- You should include a breakdown of the three lab periods with the tasks you plan to complete during each lab period.
- Specifically focusing on the data you need to gather in the lab, rather than the analysis that can be completed at home.
- Answer the following question: What part of the lab will take the longest to complete? What part of the lab take the least amount of time to complete? Why do you think so?

Introductory Questions

During the first lab period for every module you will be handed 2-3 introductory questions. They will be handed out with 30 mins remaining in the period and **MUST BE SUBMITTED** at the end of the period.

The questions are randomized from a pool of questions and can be based on any part of the lab. They are simple qualitative, short answer questions. You will not be expected to do any calculations.

Lab

Expectations:

You are expected to write up all of your work in your lab book. This includes all data, plots, calculations and observations. You are expected to complete all tasks outlined in the lab manual and answer all of the questions. Your lab write up should be a good working record of your measurements, results, and calculations. The finished lab is not meant to be a formal writeup, but a neat copy of a working lab book, so that, say in 6 months, you could use that notebook to write up a formal report or journal article. You should spend enough time to produce a clear report that the marker can understand and follow easily. If mistakes are made, they should be neatly crossed out, not erased. Only the lab notebooks should be used (i.e., no loose leaf paper).

- At the top of each page, write the title, date and page number.
- Record carefully everything you're doing as you do it using subtitles such as Procedure, Apparatus, Results, Analysis or Discussion, and Conclusion.
- Document your work with schematic diagrams where necessary.
- All original data and observations should be entered directly into the lab book. Tables and graphs must be clearly titled and the axes labelled. There is no need to repeat anything in the manual but you should make notes of what you did, with diagrams, and anything unexpected.
- Provide a clear summary of your objective in each section.
- Answer all questions posed in the lab manual. Include units and uncertainties on all measurements and propagate units and uncertainties through all calculations. You can propagate the numbers and units separately if you so choose. Also, you can include just one example of a given class of calculation performed.
- Include uncertainties on all measurements as well as a justification.
- Include an error analysis of your results (i.e. propagate your errors through all calculations). In case you've forgotten how to do this look here: Error Propagation.
- Analysis: compare your results with expected results and analyze possible sources of error. A good comprehension of the theory will be needed for this part. Where possible, suggest improvements to the methods or apparatus used.
- Provide a conclusions section.
- If you perform work beyond the scope of the lab, bonus marks may be awarded.

Additional Tips to Succeed in Lab:

These labs are designed for you to engage like an experimentalist. You are expected to explore the content and discover how to observe the theories you will learn throughout the course. You should be asking yourself questions throughout the experiment and always be recording your observations.

Questions to Ask Yourself:

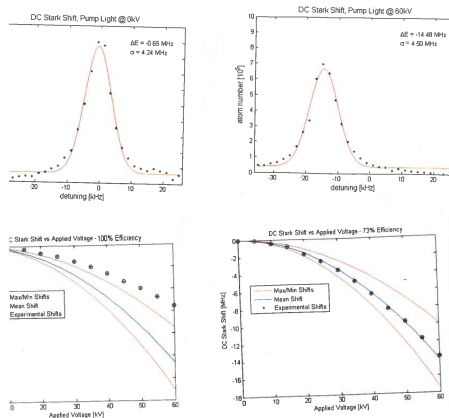
- Why?
- Does my answer make sense? If not, why?
- What could I do differently to get better results?
- Why is this important?
- What did I learn?

Examples of Lab Notebooks:

Below are examples of a good and bad lab notebook with highlights of what makes them good and bad.

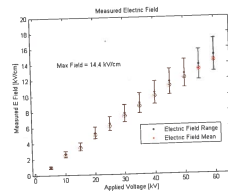
Good Notebook:

Plots are neatly pasted into book.



All plots are clearly labeled with:

- a title
- axis labels
- units
- legend



→ error bars came from treating max/min shifts as a probability region (100%).
field mean corresponds to mean shifts [ΔE]

Stark Shift Data

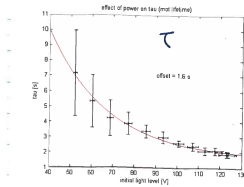
→ applied electric field after trap loading, waited 1.4sec after field on com. to ensure field was ramped (according to voltage monitor), then repumped atoms to $F=3$, and imaged on $F=3 \rightarrow F'=4$ transition. varied ΔE pump (imaging light), a peak atom Δ when on resonance allows us to see a stark shift.

Also: waited 6s after each run before reloading MOT to allow supply time to ramp down (and also get rid of static charge?)
MOT loadtime set to 5s.

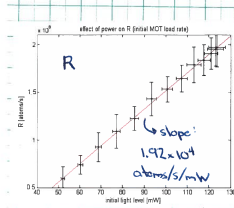
Applied Voltage [kV]	Shift [MHz]	Width [MHz]
0	-0.65	4.24
5	-0.73	4.31
10	-1.09	4.25
15	-1.45	4.09
20	-2.35	4.39
25	-3.18	4.20
30	-4.27	4.27
35	-5.56	4.13
40	-7.08	4.22
45	-8.85	4.37
50	-10.38	4.17
55	-12.36	4.51
60	-14.48	4.50

→ should get error on these points!

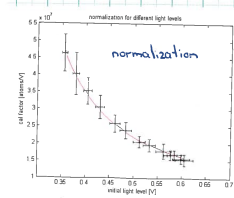
Data is neatly written in a table with headers and units



→ suggest T is
begin to level off
saturated light
assisted losses?



→ more power
would be useful if
R stays linear with
power.



↳ includes repump, so an effect to
subtract that out is needed.

In an effort to account for power fluctuations on the PD readings,
wanted to look at the cal factor (atoms/V) and how it
changed with power. Ideally, with a curve of CF vs initial voltage
(a proxy for power), I can norm everything to the right scale factor.

→ get the cal factor by taking abs images and scope traces to get
atom # vs voltage for diff sizes.
↳ also extracted R and T. (from scope traces
↳ abs seemed to give slightly larger
T and smaller R.

to fit the normalization curve:

$$N = \frac{N_{\text{cal factor (in atoms/V)}}}{A \left[\frac{h\nu}{2} R_{\text{sc}} \right]} \quad \text{where } R_{\text{sc}} = \left(\frac{3}{2} \right) \left[\frac{z/z_s}{1 + I/I_s + (2\theta/g)^2} \right]$$

↳ $I_{\text{ph}} \propto P_{\text{ph}} = W/\text{atom}$
↳ resp of pd, taking into account amount of light (solid angle)
units of $W/W \Rightarrow 1/(V \cdot \text{atom}) = \text{atoms/V}$

Equations are
neatly written
and well
labeled.

For ^{85}Rb : $\gamma = \text{natural linewidth} = (6.06 \times 10^8) \times 2\pi \text{ Hz}$
 $\Delta = \text{light detuning} \times () \times 2\pi \text{ Hz} \rightarrow \text{from data run}$
 $I_s = \text{sat. intensity} = 3.69 \text{ mW/cm}^2$

$I = \text{intensity of beams at MOT}$
↳ For curve, just used initial voltage value, but not sure how that
works. could use avg int given power/size?
however, using wrong value may just affect scaling acc
by A (fit par).

Content is neatly laid out for
easy reading and to clearly refer
back to the notes in the future.

Questions are answers
are neatly written and
easy to follow and find in
the future.

A: How long does the spin filtering stage need to be?
↳ hold atoms in 2A trap, wait 1s, then ramp down to 6A, wait
time specified, then ramp back to 2A.
expect all atoms in 12-13 state to be lost at 6A trap (see prev data).

A → looks like coils don't ramp down fast enough to see any effect for 150ms
↳ trapped atoms are not affected for the time, sounds unlikely.

B → after ~110ms, all atoms for 12-13 state lost. $1 - 2 \times 10^{-13} / 1.33 = 0.56 / 31 \approx 1.8$
↳ 66% in 12-23
↳ 33% in 13-13

⇒ Hard to ramp down for ~110ms
↳ set to 150ms just to be safe.

Ans: see lifetime change between trapping 1-12 & 1-13 and just 1-13
only 1-13 is longer (quadr. of deeper trap),
but how do the two times relate? ← ??

