University of Strathclyde

Welcome to the PH280

2nd year undergraduate teaching laboratory.

Dr. Brian Patton

Tutors + Lab. Technician

PH280 – Experimental Physics – Key initial dates

22 September	Lab. Introduction, safety & info.	GH898
	Uncertainties Lectures **Self-study**	
29 September	Experiments start: Python skills	JA 4.10
30 September		

Dr. Brian Patton
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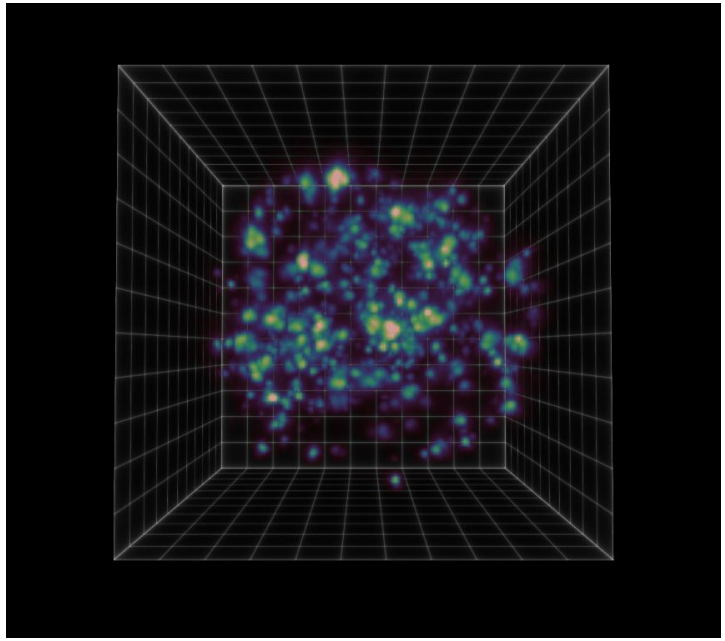
Who am I?

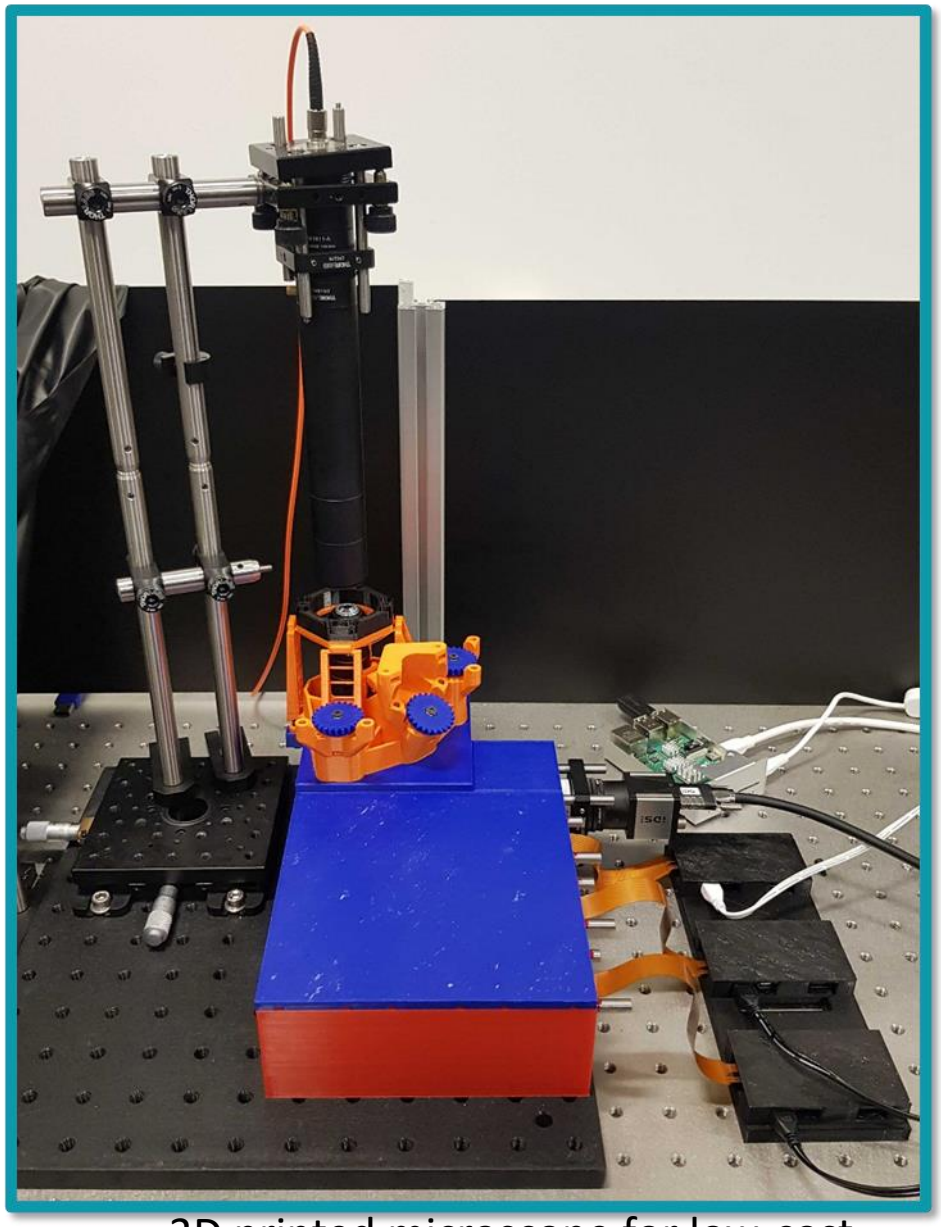
Why do I want to teach this course?

I'm a microscopist – design new types of microscopy

Interested in super-resolution microscopy – manipulating light to see things at higher resolution than historically possible.



Nanodiamond in human immune cell



3D printed microscope for low-cost imaging

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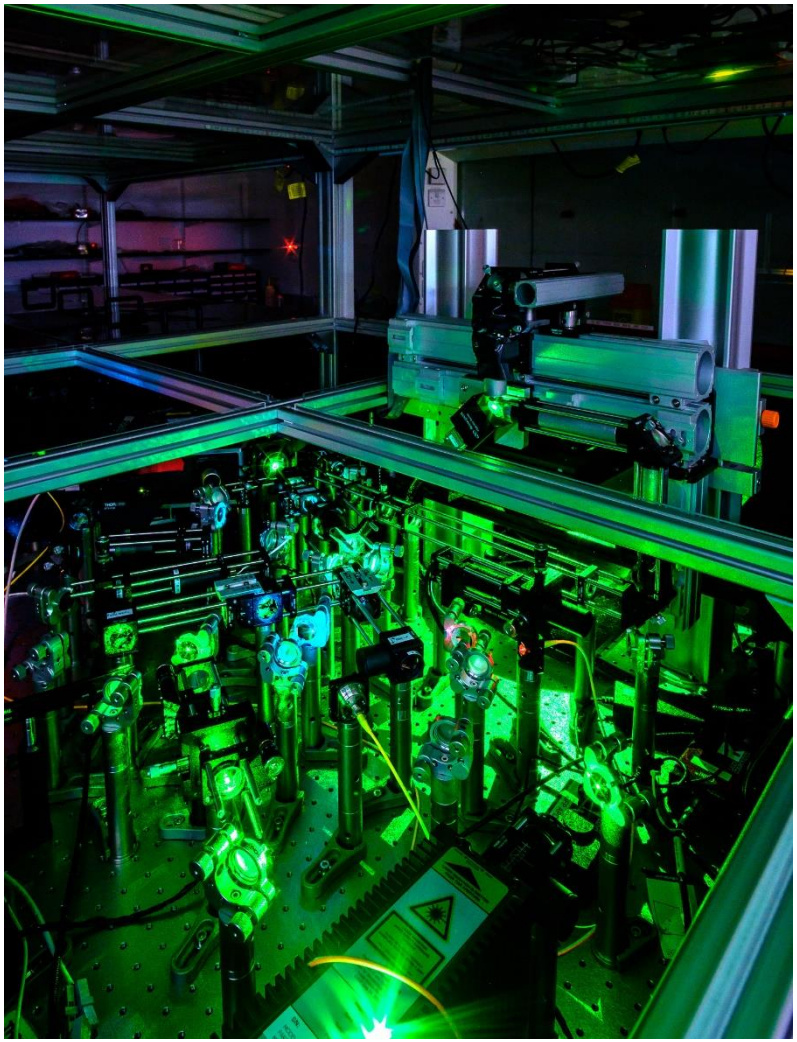
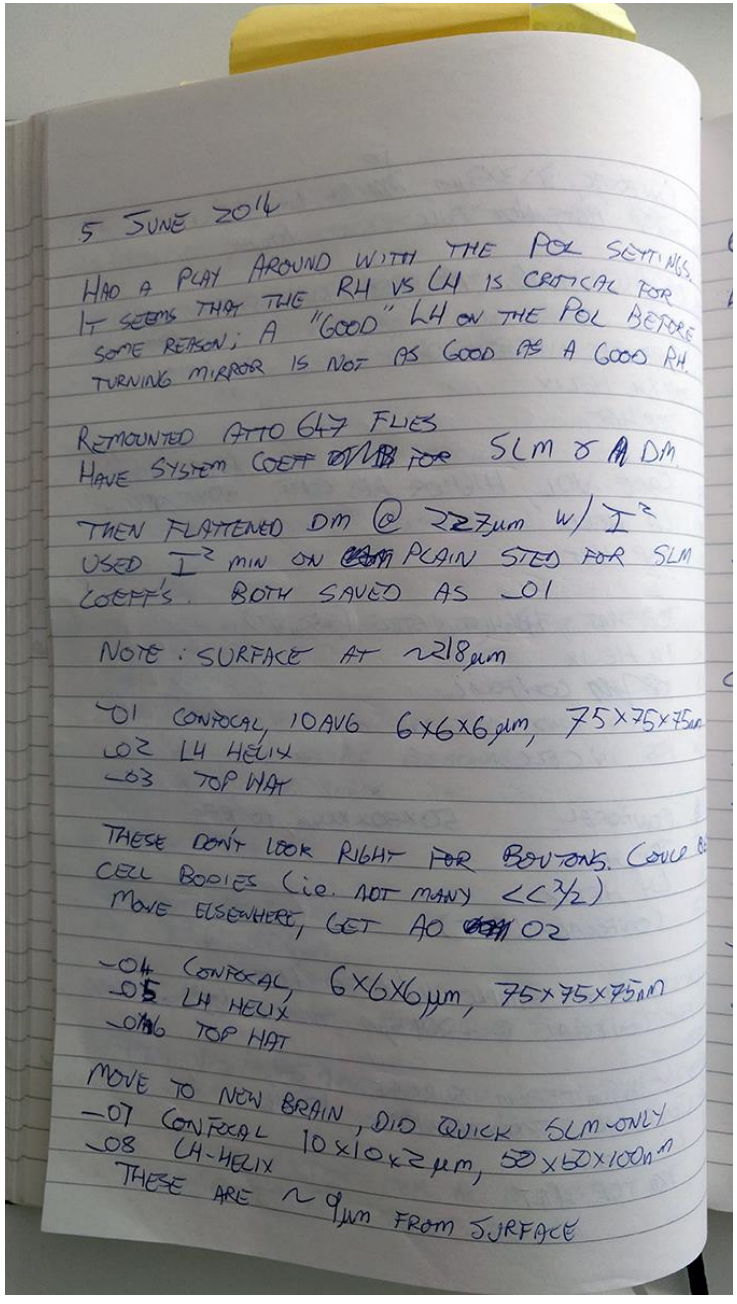
What does a super-resolution system look like?



Approx 1500 components, 4 lasers, scanners, adaptive optics, detectors……

Organisation is required!



It starts with a lab book

- Noting all key parameters
- Describing observations (and problems)
  - With sample and hardware!
- This is what this class is about
  - Get the essentials right!
- **Not** just for career as a scientist
  - Any interesting job will need these project management skills

We're using electronic lab books in PH280 this year: This is current best practise and is what our latest research lab books use

Laboratory Note Books

- We are going to use Python with Jupyter notebooks
  - Allows analysis of data
  - Can plot outputs (and save plots for use in formal reports)
  - Can make comments on your data and the experiment in general
  - Easy backup!
  - Can export a copy of your notebook (useful for sharing or making a snapshot of a particular moment in time)

- To allow effective demonstrator support, we will **not** support other data analysis software (e.g. Matlab, Excel, or Python running in a different environment)

- There is information on MyPlace on how to use and install Jupyter. Make sure to read it
- **Personal laptops are encouraged.** But there **will** be computers available for those without

Your lab book will not be marked, however it is still **essential** you document all work using it

You need to record all your calculations and analysis (**including** uncertainties calculations).

- Do **NOT** copy large sections of theory or procedure from the lab sheets, this would be a waste of your time; just give a summary of the essential details.

- It's very helpful to date sections within the lab book – you will be working on an experiment over the course of a month(including the write-up), so it will help you keep track of things

- It is essential that you add captions to figures that properly describe their contents: captions should intelligible in themselves without references to the text.

- All the notations in formulas must be explained/defined

- Use **descriptive variable names**: do **not** just call every x-value array "Xvals"

Marking will be based on reports derived from lab books

However, each person **MUST** have their own lab book and a PDF of this **MUST** be submitted as described on MyPlace for each experiment

We understand that measurements and some python code will be common to lab partners, but we **EXPECT** that the **REQUIRED** discussion within the lab book is individual to each student. Identical lab books **will be treated as plagiarism**

- Lab Safety
- Class Information

***Safety is YOUR business and responsibility at all times*.**

These notes supplement the Department's Safety Regulations and should be read carefully.

Potential hazards in Physics Laboratories

- “Common” accidents
- Fire
- Electrical
- Materials and chemicals
- Machinery
- Gas cylinders
- Ionising radiation
- Laser, UV and microwave radiation.

No food or drinks are allowed in the labs.

Tap water is not necessarily drinking water.

Wash your hands if they should come into contact with chemicals of any sort. **Check if more is required (COSSH sheets)**

"Common" Accidents **:** e.g. falling down stairs, tripping over obstacles, etc. Keep passageways clear of obstacles (e.g. bench stools, books, unused equipment) – especially in darkened labs. ***No horseplay in labs. No headphones to be used in the labs.***

We understand some students need to be able to take regular breaks. Please do so when required, observing the above rules.

***Fire* :** Unlikely but potentially fatal to many people if it should happen. Electrical equipment, especially older power supplies can go on fire if short-circuited and wrongly fused. In general, switch off unattended equipment unless there is a good reason for leaving it on.

Know where the fire exists are.

Electrical **:** Current through heart stops operation of the heart. Use safety equipment . When adjusting equipment keep one hand away from equipment and away from any earthed conductor and hence reduce current through the heart if you touch a “live” component. Know about resuscitation procedures – see notice displayed in every laboratory.

- ***Mains*** operated equipment including 5V power supplies, desk lamps, etc. Safety depends on correct wiring of plug, good quality cable, right fuse, proper earthing. “Tingly feeling” in finger when touching equipment that is not earthed.
- **Report defects to demonstrator or lab technician**.

Lasers are divided into classes

1	Harmless
2 or 3R	Low power – minor precautions needed
3B	Medium power – severe eye damage possible
4	Eye and skin damage possible.

All the lasers in the 2nd year teaching lab. are Class 2 or lower.

There are no experiments using lasers this year, but they may be in use by others in the lab at the time.

Your first accident may be one we haven't thought of yet.

BE CAREFUL!

***Safety is YOUR business and responsibility at all times*.**

Covid

It's still around, and can still have serious health implications for infected people

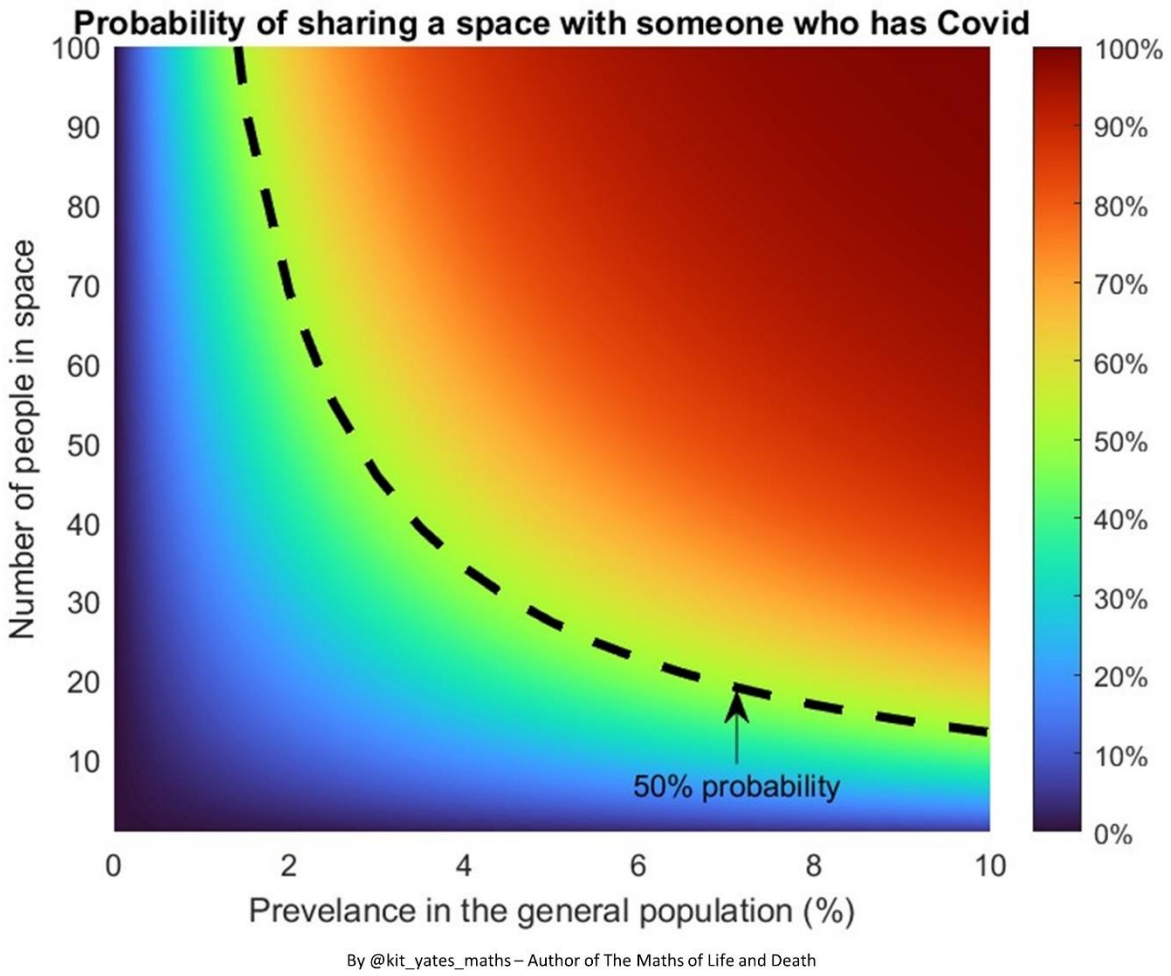
The labs are ventilated, and we have additional air filtration units this year

However, new variants are highly transmissible

PLEASE consider wearing a mask in the case that the current low rate rises

Please understand that some class members may need to wear masks regardless of the current prevalence. To normalise this, I will be wearing a mask at regular points in the year

This is not a <u>restriction,</u> it <u>enables</u> a larger fraction of the year to attend



Lab. Safety

- Class Information

Assessment

- Python Skills (S1)	(20%)
- 2x Formal Report (1 in S1, 1 in S2)	(40%)
- 2x Key Results (1 in S1, 1 in S2)	(20%)
- One Lab Practical Test (S2)	(20%)

Note: The precise hand-in dates will be on MyPlace. It is anticipated that the S1 formal report and key results will have a deadline at the very start of S2

Resit lab (you don't want to be here!!)

- Part of the summer (August) resit exam diet – you will be notified if you need to attend
- Format will be finalised in semester 2

Failing the resit labs means you fail the class completely and will therefore need to repeat this class the following year.

Lab organisation

- You will be split into two cohorts
- Cohorts attend on both days of alternate weeks
  - This means that no-one uses your equipment between days
- Within cohorts, there are sub-groups who will perform a given experiment
- You will work with a lab-partner
- Details of cohort and group assignment will be on MyPlace

PH280 - Experimental Physics

Week	2022	SEMESTER 1	2023	SEMESTER 2
		Thursday 13:00 - 17:00 and Friday 1300-1700		
1	19-September	Thurs - Lab. Introduction, safety & info.	19-January	Normal Expt. Starts.
			20-January	
2	29-September	Python Skills (In JA4.10)	26-January	
	30-September		27-January	
3	06-October	Python Skills (In JA4.10)	02-February	
	07-October		03-February	
4	13-October	Python Skills (In JA4.10)	09-February	
	14-October		10-February	
5	20-October	Python Skills (In JA4.10)	16-February	
	21-October		17-February	
6	27-October	Normal Expt. Starts	23-February	
	28-October		24-February	
7	03-November		02-March	Lab Practical Test
	04-November		03-March	Last week of normal lab.
8	10-November		09-March	
	11-November		10-March	
9	17-November		16-March	
	18-November		17-March	
10	24-November	No Labs	23-March	
	25-November		24-March	
11	01-December	No Labs	30-March	
	02-December		31-March	

PH280 - Experimental Physics

Week	2019	SEMESTER 1	2020	SEMESTER 2
		Thursday 13:00 - 17:00 and Friday 1300-1700		
1	19-September	Thurs - Lab. Introduction, safety & info.	19-January	Cohort 2
			20-January	
2	29-September	Cohort 1 - Python	26-January	Cohort 1
	30-September		27-January	
3	06-October	Cohort 2 - Python	02-February	Cohort 2
	07-October		03-February	
4	13-October	Cohort 1 - Python	09-February	Cohort 1
	14-October		10-February	
5	20-October	Cohort 2 - Python	16-February	Cohort 2
	21-October		17-February	
6	27-October	Cohort 1	23-February	Cohort 1
	28-October		24-February	
7	03-November	Cohort 2	02-March	Cohort 1 – Lab. Practical test
	04-November		03-March	Cohort 2 – Lab. Practical test
8	10-November	Cohort 1	09-March	
	11-November		10-March	
9	17-November	Cohort 2	16-March	
	18-November		17-March	
10	24-November		23-March	
	25-November		24-March	
11	01-December		30-March	
	02-December		31-March	

Reminder:

Assigned groups (cohort and sub-group) are on Myplace.

Assigned expt. will be posted on notice board and on Myplace.

Experiments' scripts are available on Myplace only.

Lab Attendance

Lab attendance for this 20-credit module is **compulsory**, and you must sign in on the sheets provided and sign out at the end of the session. Absences are noted and will be followed up.

Note: in Strathclyde, there is an expectation of 10 hours work per credit. This means there is 200 hours work in this module.

There are 62 hours of labs and lectures planned. That means that for **every 1 hour** of lab time, there is an expectation of **3 hours of self study.**

Key self-study activities:

- Reading handouts and revising relevant physics **ahead of the labs**
- Writing reports and key results hand-ins

Statistical Uncertainties lectures

The uncertainty lectures cover key concepts in treating uncertainties. These lectures are a compulsory part of the module – you are expected to do uncertainty calculations in every experiment! Due to the extra closure day, there is no timetabled slot to discuss them – your demonstrators can help with material you found difficult in the Python Skills sessions

Python Skills

The handouts for the Python Skills experiments will be available at the end of week 1, along with information on installing Jupyterlab

Experiment Information Sheets

The experiments will be made available on MyPlace during the last week of the Python Skills experiment:

- You should print out and read the script **before** you start the lab as it will help you to understand the experiment better
- There will be no lab script provided
  - **Bring your own**

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Laboratory Note Books

- You will be using Jupyterlab for note taking. Ideally, data should be recorded directly onto the Jupyterlab notebook you are using for that experiment
  - You can use your own computing devices for this
  - If using loose paper (e.g. when using the lab's computers), minimise the time that the data is not on the computer
- SAVE THE NOTEBOOK to Onedrive or your i-drive. In general, lost data files are not reason for an exemption – the university provides you with backed-up cloud storage.
  - If you're not sure what this means, use the Python Skills session to discuss with your demonstrators how to make sure your data is being safely saved

- While the readings in a dataset will be shared between lab partners, **JUPYTERLAB NOTEBOOKS MUST NOT BE SHARED.** Each lab partner should have their own copy of the data in their own Jupyterlab notebook with their own comments and discussion.

The lab book is for you to record your experimental data and what you have done (not repeat what the lab script says)
You need to record all your calculations and analysis (**including** uncertainties calculations).

- Do **NOT** copy large sections of theory and procedure from the lab sheets, this would be a waste of your time; just give a summary of the essential details.

- Figures and tables must be numbered in the order of their appearance in the lab book. They must have captions intelligible in themselves without references to the text. You will practise adding captions to figures in the Python Skills experiment.

- All the notations in formulas must be explained/defined.

- You will be expected to upload a PDF of your labbook for each experiment to Myplace. Details of how and when to do this will be posted there. This will not be directly assessed, but will form a record that may be used if there are potential problems with plagiarism. Missing records will be considered as evidence of evasion.

We are scientists!

Always give ***units*** and consider the number of ***significant figures*** quoted in results.

Acceptable are results written as, for example:

$$(9.34 \pm 0.06)\ Vs^{-1} \text{ or } (9.342 \pm 0.014) \times 10^{-5}\ s$$

rather than ~~$(9.3 \pm 0.0612)\ Vs^{-1}$~~ or ~~$(9.342 \times 10^{-5} \pm 0.0000014)s$~~.

(Note the same number of decimal places and/or same $x10^n$ factor used for result and uncertainties).

You will practise presenting results in this format in the Python Skills session.

What do we want to see from reports and key results?

Lab Book vs Key Results vs Formal Report

Lab Book

- Title and Date
- Comments on preparation for data acquisition
- Measurement and Analysis
- Comments/Observations/Summary
- **PLOTS!**
- References

Key Results

- Title and Date
- Aim of experiment
- Results and Analysis
- Discussion of results

Formal Report

- Title and Date
- Abstract
- Introduction
- Theory
- Experimental
- Results and Analysis
- Discussion
- Conclusion
- References
- Appendix

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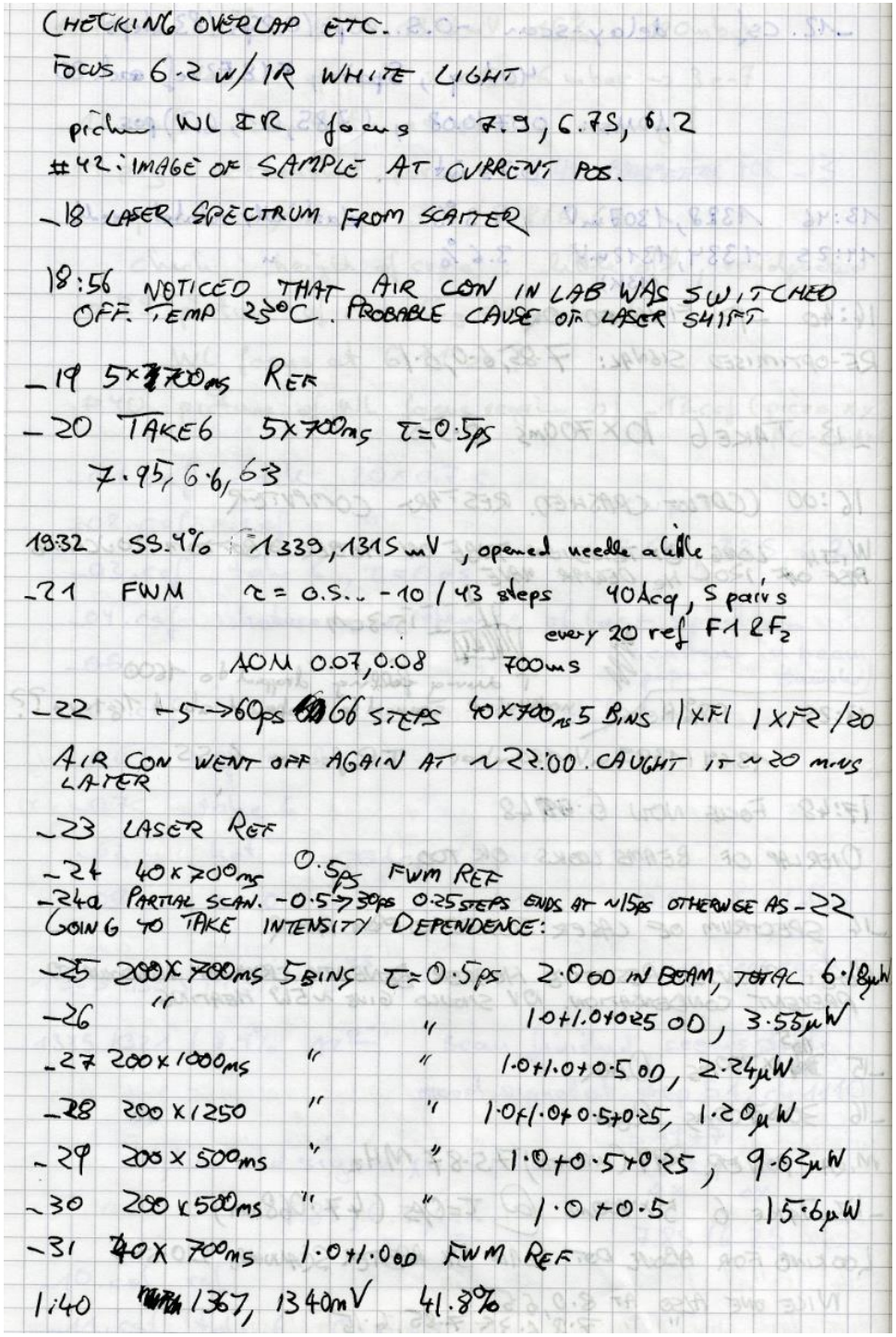
Marking Scheme for Experiments

What is the basis for the lab marking scheme?

- Labs are not like other classes
  - Wide range of skills we are trying to impart
- You work closely with the demonstrators
  - Excellent opportunity for feedback based marking
- We want to change the way you work
  - More than just meeting a checklist of requirements
- **Key results** – can you summarise the experiment with just enough information to allow a reader to make a judgement on your work?
- **Formal report** – practise in writing a longer report that fully explains the motivation, approach, results and implications of the experiment


CHECKING OVERLAP ETC.
FOCUS 6.2 W/ IR WHITE LIGHT
pichu WL IR focus 7.3, 6.75, 6.2
#42: IMAGE OF SAMPLE AT CURRENT POS.
-18 LASER SPECTRUM FROM SCATTER
18:56 NOTICED THAT AIR CON IN LAB WAS SWITCHED OFF. TEMP 25°C. PROBABLE CAUSE OF LASER SHIFT
-19 5×700ms REF
-20 TAKE6 5×700ms τ=0.5ps
7.95, 6.6, 6.3
1932 55.4% 1339, 1315mV, opened needle a little
-21 FWM τ = 0.5... -10 / 43 steps 40Acq, 5 pairs
every 20 ref F1 F2
AOM 0.07, 0.08 700ms
-22 -5→60ps 66 STEPS 40×700ms 5 BINS 1×F1 1×F2 /20
AIR CON WENT OFF AGAIN AT ~22:00. CAUGHT IT ~20 MINS LATER
-23 LASER REF
-24 40×700ms 0.5ps FWM REF
-24a PARTIAL SCAN. -0.5→30ps 0.25STEPS ENDS AT ~15ps OTHERWISE AS -22
GOING TO TAKE INTENSITY DEPENDENCE:
-25 200×700ms 5BINS τ=0.5ps 2.000 IN BEAM, TOTAL 6.18μW
-26 " " 1.0+1.0+0.25 OD, 3.55μW
-27 200×1000ms " " 1.0+1.0+0.5 OD, 2.24μW
-28 200×1250 " " 1.0+1.0+0.5+0.25, 1.20μW
-29 200×500ms " " 1.0+0.5+0.25, 9.62μW
-30 200×500ms " " 1.0+0.5 15.6μW
-31 40×700ms 1.0+1.000 FWM REF
1:40 1367, 1340mV 41.8%

What do we want to see?

- The lab book shown is mine (from my PhD)
- Shows key details about the experiments
- Shows comments on when problems occurred
- Is clearly laid out
- (Not shown) Sketches of important experimental details
- All data was visualised <u>at moment of acquisition!</u>

This was clear enough that the data is still being used 14 years later!

We're not marking the lab books, but if you keep a good lab book, then you will get <u>much</u> more effective support from your demonstrators.

Common Mistakes observed in lab books

- No or few words.
- No date.
- Symbols in equations are not defined.
- Acronyms are used which are not defined.
- A beautiful diagram of apparatus is given but there is no labelling
- There are acronyms in the diagram of apparatus which are not defined.
- Axes on graphs are not labelled.
- Graphs/tables not labelled, i.e., no figure title, number.
- Beautiful graphs and tables are presented but there is no commentary of what they mean.
- Missing units.
- Missing uncertainties.
- A result and its uncertainty is incorrectly stated.
- Making a statement in the discussion but not backing it up with evidence.
- Making a statement in the discussion which contradicts the results presented.
- Not discussing the significance of a result.

Formal Reports

	%	Explanation	%
Section A – General			
Title & Date	5	Title & Date. Name and registration number of the author?	
Section B			
Abstract	10	Is the abstract a clear concise summary of the principal facts and conclusions?	
Introduction	10	In well-written paragraphs: (a) Does the Introduction convey the aim of the experiment? (b) Does the Introduction put the experiment into context, i.e., does it provide a description to the background to the experiment? (c) references.	
Theory & Experimental	15	Is the theory presented appropriate and correct : (a) Is the theory clearly explained; (b) Are all symbols in equations defined? (c) Are the appropriate constants given? (d) Are units correct? (e) Are equations numbered in sequence? (f) references. (g) Is there a description of a suitable practical experimental method to perform the measurements?	
Results and Analysis:	20	In well-written paragraphs: (a) Is the relevant data clearly presented in either tables or graphs? Note the data should be presented in only one format, i.e, either a table or a graph. Note make sure you chose the best way to present the data. The students may present their graphs in the main body of the report and put their tables of data in an appendix. The main results should NOT be placed in an appendix. (b) If tables are included are they correctly titled, labelled and are units given? Note tables of raw data should be in the Appendix. (c) Are graphs correctly titled, labelled and units given? (d) Presents the main calculations/results done in the experiment with values and uncertainties having correct significant figures and units.	
Discussion	15	In well-written paragraphs: (a) Interprets and explains the results correctly, and if applicable, compares the expected results with the actual results, (b)Are final results presented with uncertainties? Are the final results and uncertainties given with the correct number of significant figures? (c) Is there a clear discussion of the implications of the results? Results should be compared with published data where appropriate and references given. (d) Explain how the results show the purpose was achieved, or if not achieved, explain why.	
Conclusion	10	Are there clear conclusions? Summaries the main points of the experiment precisely. This includes the significant numerical results with uncertainties, units and comparison to the accepted values where appropriate.	
References	10	(a) Are references included? (b) Are they indicated correctly in the text? (c) Has the Harvard or Vancouver system been correctly used (if appropriate, i.e., web references or references to lab notes are acceptable). (d) Internet reference should be less than 10%.	
Appendix	5	This is where the details of the followings are given: (a) tables of raw data (titled, labelled, units given); (b) non essential additional figures (titled, axis labelled, units given); (c) uncertainties calculation (detail calculations, assumptions made, approximation taken etc.)	
Total marks (%)	100	**Total marks (%)**	0

Example of a formal report marking scheme.

(Final marking scheme will be released with the formal report info)

The marking aims to reflect the full range from 0 to 100.

In the context of lab write-up, marked out of 100 :

'40' means the work is poor and really needs to be re-done.

'50' is barely acceptable.

'60' is reasonably good.

'70' is very good.

Marks above '70' are excellent.

KEY RESULTS (Note: 2-3 pages maximum)

Experiment : _____

Student name : _____ Registration # : _____

Marker: _____

	%	Explanation	%
Section A – General			
Title & Date	5	Title & Date. Name and registration number of the author?	
Section B			
Aim	15	State the aim of the experiment	
Results and Analysis	60	(a) Is the relevant data clearly presented in either tables or graphs? (b) Tables/graphs correctly titled, labelled and units given? (c) Presents the **main calculations/results** done in the experiment with values and **uncertainties** having correct significant figures and units.	
Discussion	20	(a) If applicable, compares the expected results with the actual results (b) Brief discussion of the implications of the results? Results should be compared with published data where appropriate and references given. (c) Briefly explain how the results show the purpose was achieved, or if not achieved, explain why.	
Total marks (%)	100	**Total marks (%)**	0

Example of a key results marking scheme.

(Final marking scheme will be released with the formal report info)

Much shorter (aim for between 2 and 3 pages)

Summarise the key results to someone who knows the experiment well

Still need to present data in some appropriate format (e.g. plots or tables)

Still need a summary discussion that explains your results

TITLE : HOW TO KEEP A LABORATORY RECORD for the 2nd-yr. lab
(give a title to the day's experiment)

DATE : 15th October 2023
(It is important that you note the date you did the expt.)

ABSTRACT :

I suggest you write this section last. This should be the summary of what the experiment is about, the experimental results, and conclusion.

Example Abstract 1

Particles of diamond in the 5 to 100nm size range, known as nanodiamond, have shown promise as robust fluorophores for optical imaging. We demonstrate here that, due to their photostability, they are not only suitable for two-photon imaging, but they allow significant resolution enhancement when combined with computational super-resolution techniques. We observe a resolution of 42.5nm when processing two-photon images with the Super-Resolution Radial Fluctuations algorithm. We show manipulation of the point-spread function of the microscope using adaptive optics. This demonstrates how the photostability of nanodiamond can also be of use when characterising adaptive optics technologies or testing the resilience of super-resolution or aberration correction algorithms.

From: https://doi.org/10.1098/rsos.190589

Example Abstract 2

We present an analysis of time- and polarization-resolved data taken in micro-photoluminescence (μ-PL) experiments on individual CdSe/ZnSe quantum dots grown by molecular beam epitaxy. The identification of individual dots was performed by a spectral jitter correlation technique and by their polarization properties and density dependencies. Decay times are given for exciton, trion and biexciton states and evidence is shown for a spin-relaxation limited energy relaxation of the trion. For the bright exciton state the temperature-dependence of the decay time is studied and a repopulation from the dark exciton state is observed. Trion binding energies of 15 - 22meV and biexciton binding energies of 19 - 26meV are found.

From: http://dx.doi.org/10.1103/PhysRevB.68.125316

Example Abstract 3

In this experiment it was shown that a tungsten filament bulb behaves much like a blackbody and therefore its radiating properties can be related to Stefan's Law. To confirm this, a simple circuit was set up to measure the current flowing through the filament with a varied D.C. voltage applied. These quantities were then related to power output and temperature enabling a comparison to be made with Stefan's Law. It was found that the power output per unit area was proportional to T^4.

Introduction

- Does not include any discussion of the results!
- Why is this interesting physics?
- Possible historic context
- Brief (but longer than abstract)

Theory / Experimental (Methodology)

- Much more detailed than the abstract
- Describes the background to the experiment and what it aims to achieve (the whats and whys)
- May discuss theoretical aspects and derive any relevant formulae
- Put your experiment in context

Theory

- Most experiments set out to test a theory, or rely on theory for their interpretation
- Summarise the theory, and define all terms used in the text and in equations, so that the reader can understand what follows.
- Important equations should be numbered, so that they can be referred to later in the report.

This should be very brief and only includes parts you actually use in the experiment.

Do **NOT** copy large section from the lab script. (~ half a page)

Experimental method and details

- Describes how the experiment was performed (in general term, not a step by step account). What you did not what the script
- Discusses equipment and materials/samples used
- List any special or extra precautions taken, if any
- Will generally contain a diagram or sketch of the equipment – but do not list the equipment.

Do **Not** copy large section from the lab. script. (~ half a page)

For example :

" The simple pendulum comprised of a bob attached to a length of light string as shown in figure 1. The bob was displaced through a small angle and time taken for the pendulum to oscillate through 10 oscillations was recorded for a given length. This process was repeated for different of lengths."

Results and Analysis or **Measurement and Analysis**

Think of this as either **READINGS** or **MEASUREMENTS**

'Results' are really what you obtain as a result of manipulation of your readings or measurements.

You should always record the '**raw**' data, i.e. the data you actually measured, not the 'result' after you have manipulated it. This does not need to be included in a formal report in the same way that it was recorded in your notebook (e.g. you might write down a table of readings but only show the plot of them in your report)

Results and Analysis or **Measurement and Analysis**

- Describe your ***results***
- Discuss the sources of ***uncertainty***
- Analyse the effect these ***uncertainties*** have on your results
- ***Discuss*** what your results mean i.e. draw conclusions from your results
- Three ways to present results – ***text, tables, figures***
    - ***Figures are usually the most appropriate way to present data***
- There are multiple types of suitable figure (including graphs, drawings, charts, plots…)
- All tables and figures should have a *figure number and must have a caption* and you should refer to the figure by number ***not*** like *"as can be seen in the figure below"*

All tables and figures must have a ***caption*** (title), the axes of all graphs must be ***labeled*** and the ***units*** used should be given.

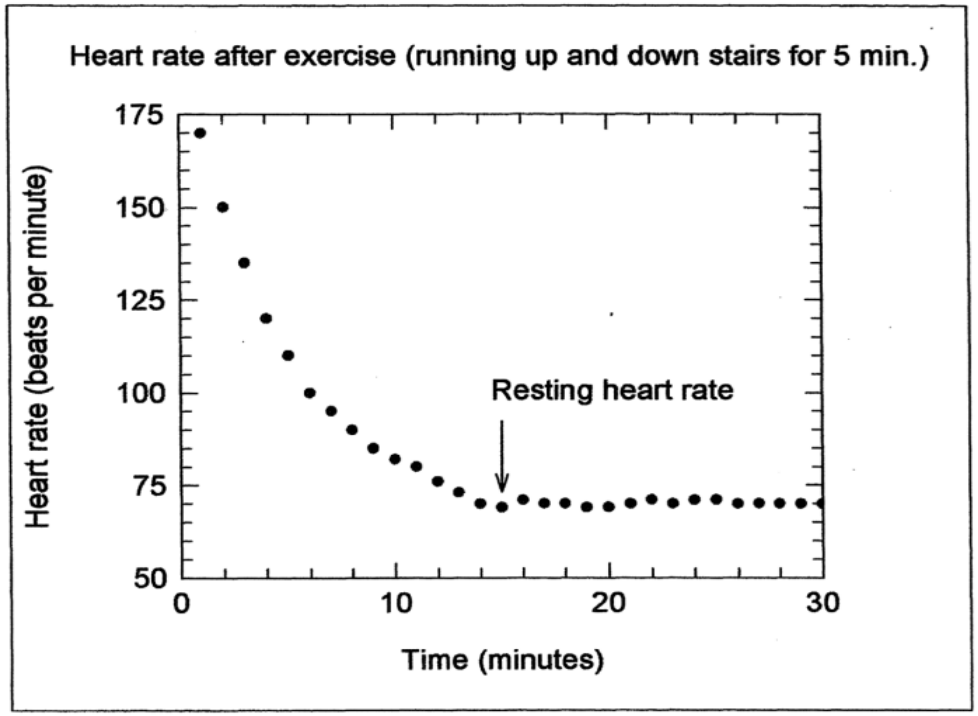


Figure 2. Heart rate as a function of time after exercise (running up and down stairs for 5 minutes)

Time (minutes)	Heart rate (beats per minute)
1	170
2	150
3	135
4	120
5	110
6	100
7	95
8	90
9	85
10	82
11	80
12	76
13	73
14	70
15	69
16	71
17	70
18	70
19	69
20	69
21	70
22	71
23	70
24	71
25	71
26	70
27	70
28	70
29	70
30	70

Table 1. Heart rate as a function of time after exercise (running up and down stairs for 5 minutes)

Don't forget the uncertainties calculations. Remember that uncertainty consideration should be kept in perspective. The idea is that with experience it should not take up a disproportionate amount of time. However, it should always be present

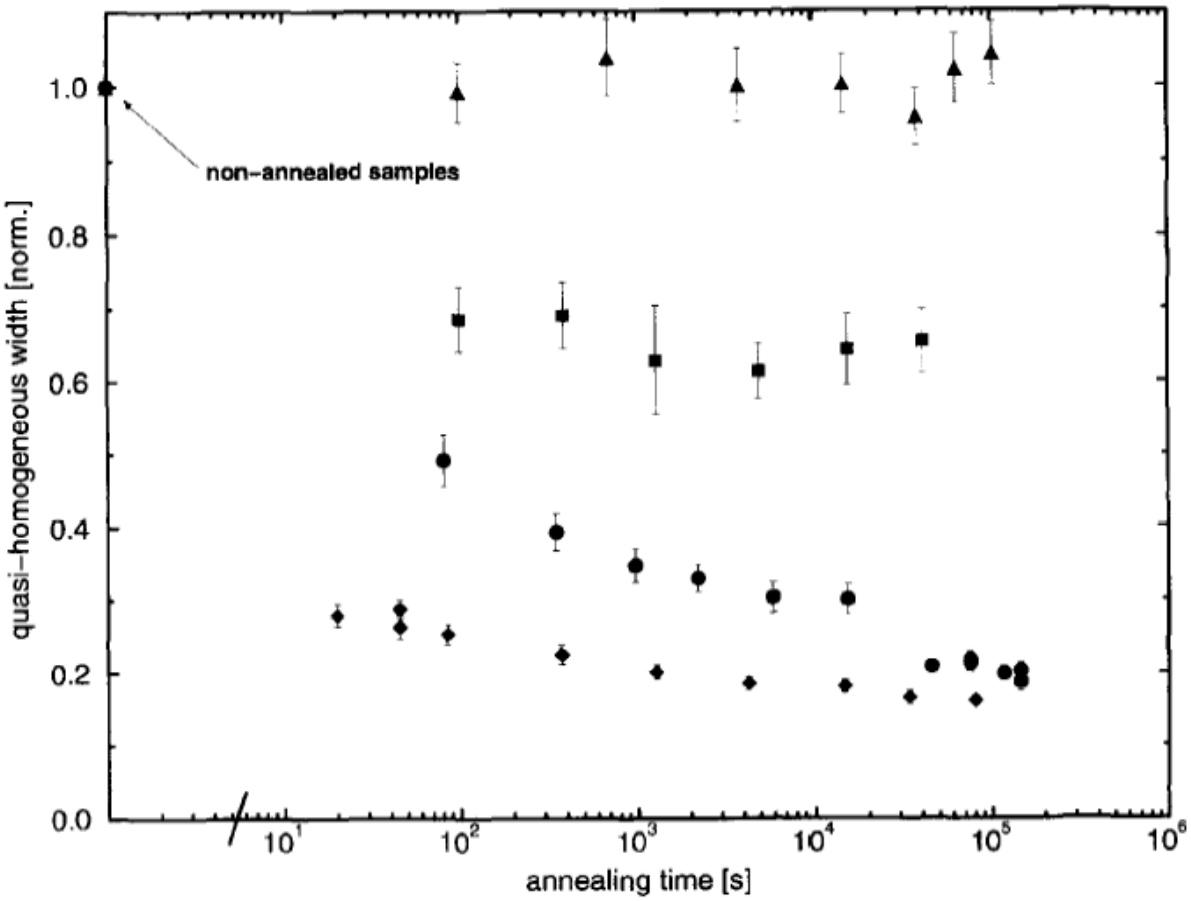


Fig. 4. Kinetics of the narrowing of the quasi-homogeneous line width during annealing at 49 K (▲), 70 K (■), 103 K (●), and 122 K (◆).

Discussion or **Comments/Observations/Summary**

Discussion is where you can discuss your results, findings, insights etc. of your experiment.

Don't forget to discuss the uncertainties in the experiment, however, it should not take up a disproportionate amount of space (it should not be more than 10% to 20% of your discussion).

You should **refrain** from using throwaway lines such as:
'human or reading errors' (this really means you didn't do the experiment properly)
'use better or more accurate equipment' (this only shows poor experimental skills)

- Focus on the main results of experiment
- Compare with theoretical predictions
- If more than one technique has been used then separate results should be compared
- If possible compare results with previously published values (data or reference books etc)
- Discuss any discrepancies
- Discuss any possible improvements

How do we reference?

There are multiple styles of referencing and you may see the style referred to by name. We use the **Vancouver/Numeric** system:

- When we are making a reference in the text we use the ref's number by writing it as [1], (1) or [1] (for reference number 1)
- The list of references should then be ordered in the order which the reference first appears in the main text
- If you are referring to something multiple times, you only need to have it in the reference list once, and you should use the number when it first appears (e.g. "as was shown in references [3,7,67-80]")

The reference list will then be written like:

1. Evgenious, M., *Inorg. Chem.,* 2005, 44 (21), pp. 7511 – 7522.

2. 2nd year PH280 lab. script 2016. Department of Physics, University of Strathclyde, Glasgow.

(use "**et. al.**" only if there are more than 5 authors)

The order in which author, name, journal etc. appears should be consistent within the list: in published articles the ordering is decided by the editors of the journal in which the article appears and can vary from journal to journal

Example Referencing: Bracketed

The first applications of NV centres in diamond to magnetic field measurements were reported in 2008 [2,3], and since then sensitivities have been increased greatly and the number of applications has grown. The first images of magnetic field distributions produced by microscopic current distributions were obtained in 2011 [6].
Since then images have been obtained of magnetic particles as small as 20 nm [7] and of magnetosomes inside magneto-tactic bacteria [8].

References

1. F. Jelezko, J. Wrachtrup, Phys. Stat. Sol. A 203, 3207 (2006)
2. 2. G. Balasubramanian, I.Y. Chan, R. Kolesov, M. Al-Hmoud, J. Tisler, C. Shin, C. Kim, A. Wojcik, P.R. Hemmer, A. Krueger, T. Hanke, A. Leitenstorfer, R. Bratschitsch, F. Jelezko, J. Wrachtrup, Nature 455, 648 (2008)
3. 3. J.R. Maze, P.L. Stanwix, J.S. Hodges, S. Hong, J.M. Taylor, P. Cappellaro, L. Jiang, M.V. Gurudev Dutt, E. Togan, A.S. Zibrov, A. Yacoby, R.L. Walsworth, M. Lukin, Nature 455, 644 (2008)
4. 4. L. Rondin, J.-P. Tetienne, T. Hingant, J.-F. Roch, P. Maletinsky, V. Jacques, Rep. Prog. Phys. 77, 056503 (2014)
5. 5. R. Schirhagl, K. Chang, M. Loretz, C.L. Degen, Annu. Rev. Phys. Chem. 65, 85 (2014)
6. 6. L.M. Pham, D. Le Sage, P.L. Stanwix, T.K. Yeung, D. Glenn, A. Trifonov, P. Cappellaro, P.R. Hemmer, M.D. Lukin, H. Park, A. Yacoby, R.L. Walsworth, New J. Phys. 13, 045021 (2011)

From: https://doi.org/10.1051/epjap/2016150449

Example Referencing: Superscript

Phase-sensitive, interferometric imaging measures small changes in the time-of-flight of a light wave by detecting changes in its phase. But in many applications, statistically varying optical properties of the scattering structure randomize the phase of the backscattered light, resulting in a speckle pattern with random intensity and phase[1]. As a consequence, we can only extract meaningful phase differences from images with identical or at least almost identical speckle patterns[2]. However, if the detected wave's speckle pattern changes over time, it inevitably impedes phase sensitive imaging[3,4].

References

1. Goodman, J. Speckle Phenomena in Optics: Theory and Applications (Roberts & Company, 2007).
2. Creath, K. Phase-shifting speckle interferometry. Appl. Opt. 24, 3053–3058, https://doi.org/10.1364/AO.24.003053 (1985).
3. Joenathan, C., Haible, P. & Tiziani, H. J. Speckle interferometry with temporal phase evaluation: influence of decorrelation, speckle size, and nonlinearity of the camera. Appl. Opt. 38, 1169–1178, https://doi.org/10.1364/AO.38.001169 (1999).
4. Lehmann, M. Decorrelation-induced phase errors in phase-shifting speckle interferometry. Appl. Opt. 36, 3657–3667, https://doi.org/10.1364/AO.36.003657 (1997).

From: https://doi.org/10.1038/s41598-019-47979-8

Timetable recap

University of Strathclyde

PH280 - Experimental Physics

Week	2022	SEMESTER 1	2023	SEMESTER 2
		Thursday 13:00 - 17:00 and Friday 1300-1700		
1	19-September	Thurs - Lab. Introduction, safety & info.	19-January	Normal Expt. Starts.
			20-January	
2	29-September	Python Skills (In JA4.10)	26-January	
	30-September		27-January	
3	06-October	Python Skills (In JA4.10)	02-February	
	07-October		03-February	
4	13-October	Python Skills (In JA4.10)	09-February	
	14-October		10-February	
5	20-October	Python Skills (In JA4.10)	16-February	
	21-October		17-February	
6	27-October	Normal Expt. Starts	23-February	
	28-October		24-February	
7	03-November		02-March	Lab Practical Test
	04-November		03-March	Last week of normal lab.
8	10-November		09-March	
	11-November		10-March	
9	17-November		16-March	
	18-November		17-March	
10	24-November	No Labs	23-March	
	25-November		24-March	
11	01-December	No Labs	30-March	
	02-December		31-March	

PH280 - Experimental Physics

Week	2019	SEMESTER 1	2020	SEMESTER 2
		Thursday 13:00 - 17:00 and Friday 1300-1700		
1	19-September	Thurs - Lab. Introduction, safety & info.	19-January	Cohort 2
			20-January	
2	29-September	Cohort 1 - Python	26-January	Cohort 1
	30-September		27-January	
3	06-October	Cohort 2 - Python	02-February	Cohort 2
	07-October		03-February	
4	13-October	Cohort 1 - Python	09-February	Cohort 1
	14-October		10-February	
5	20-October	Cohort 2 - Python	16-February	Cohort 2
	21-October		17-February	
6	27-October	Cohort 1	23-February	Cohort 1
	28-October		24-February	
7	03-November	Cohort 2	02-March	Cohort 1 – Lab. Practical test
	04-November		03-March	Cohort 2 – Lab. Practical test
8	10-November	Cohort 1	09-March	
	11-November		10-March	
9	17-November	Cohort 2	16-March	
	18-November		17-March	
10	24-November		23-March	
	25-November		24-March	
11	01-December		30-March	
	02-December		31-March	

Example Experiment Assignment (See MyPlace for this year's assignments)

Demonstrator	T3	T2	T1	T3	T1	all	T4	T2
PH280 (2019/20) Semester I	1- AC circuits	2- Analogue Electronics	3- Fourier Series	4- Hall Effect	5- Kater's pendulum	9- Lab Skills	6- Michelson	7- Stefan's Law
Cohort 1 Group								
A				6		4	8	
B		8			6	4		
C			8			4		6
D						4	6	8
E	6			8		4		
F	8		6			4		

University of Strathclyde