Second year laboratory: Formal report writing

November 2022

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(After Chris Bell 2020)

Purpose of this talk

- To provide an *introductory guide* to important things you should and should not include in a formal report.
- This is NOT meant to be an exhaustive, prescriptive lesson.
- Remember there is also *information in the lab handbook*.

Formal reports are due on Fridays of week 14 (3rd Feb 2023) and week 23 (28th April 2023)

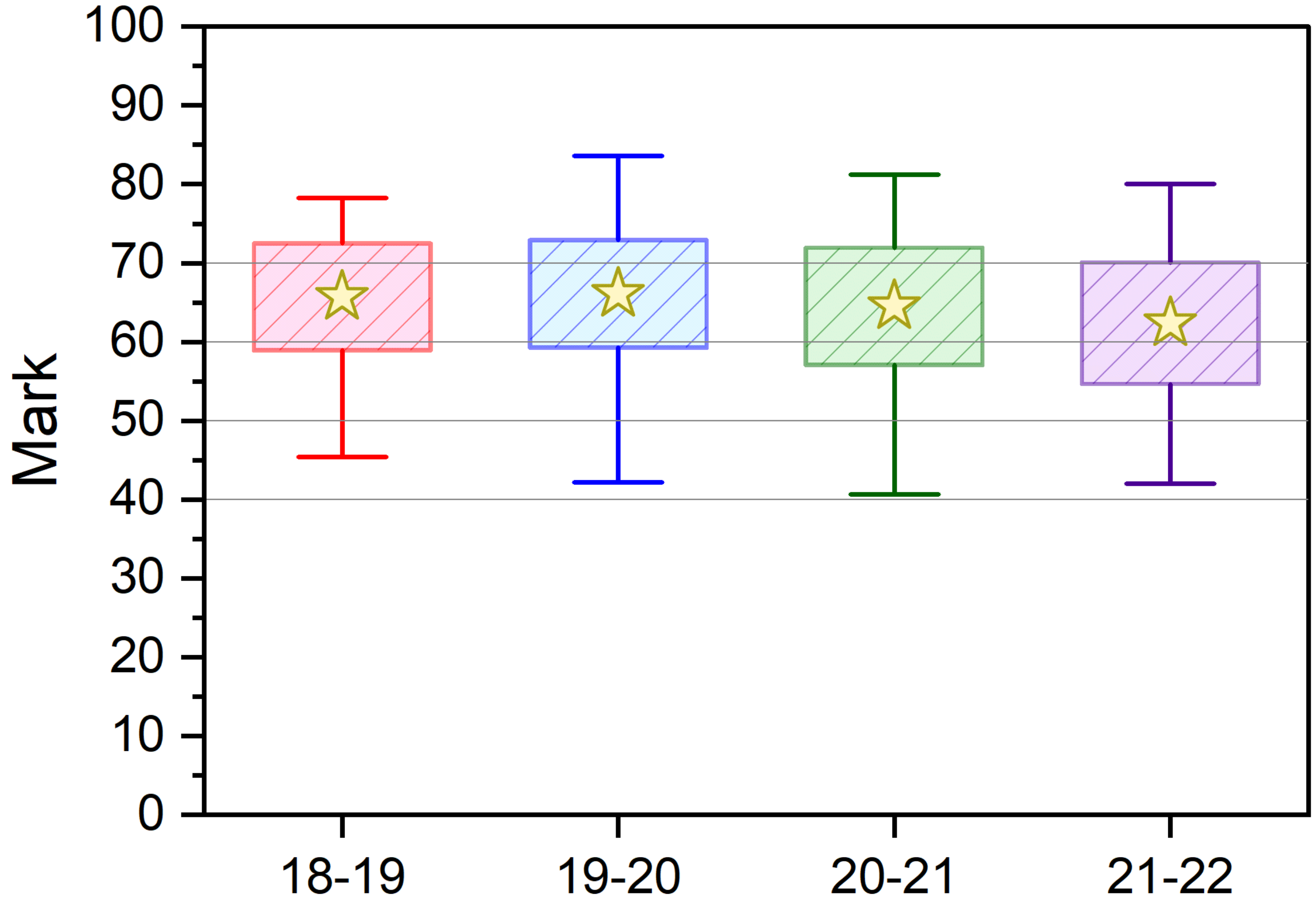
Number of Experiments

Course	Unit Code	Lab Element	Weeks	# Expts	Formal Report
Physics, Physics w/ Astrophysics, Physics w/ Industrial Experience etc.	*PHYS29026*	222	2-23	5	FR1 **and** FR2
Physics w/ Innovation & Theoretical Physics	*PHYS29010*	201	2-10	2	FR1
Physics w/ Study in Europe[1]	*PHYS29010*	201	2-10 *or* 15-23	2	FR1 *or* FR2
Mathematics and Physics & Physics and Philosophy	*PHYS29010*	201	15-23	2	FR2
Chemical Physics	*CHEM20006*	201	2-10	2	FR1

Assessment

Unit	Lab Experiments	Formal Report(s)	Conference
201	60%	30%	10%
222	65%	30%	5%

Overall mark distribution: four year period



Marking statistics from a formal report

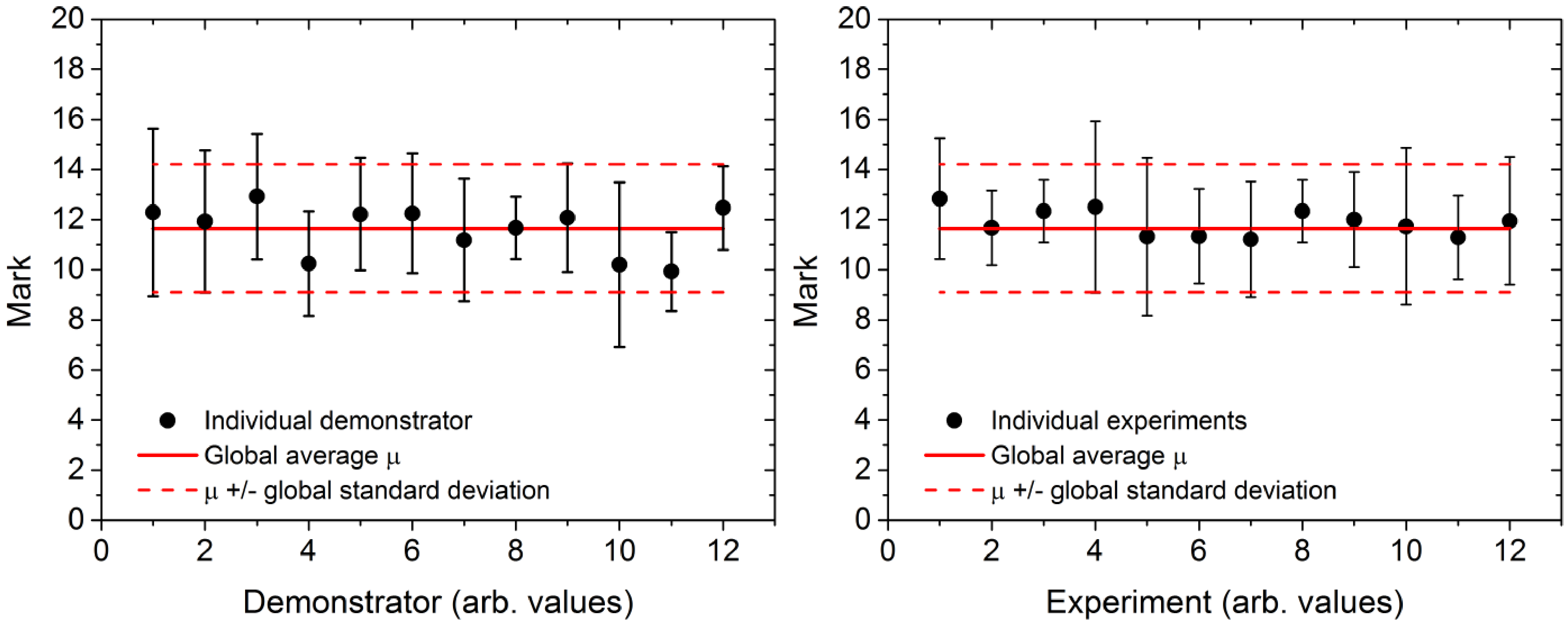


Figure 1: Average mark versus demonstrator (left) and experiment (right). Error bars are the population standard deviation for each demonstrator or experiment. Solid lines show the global average (μ) for all marks. Dashed lines are $\mu \pm \sigma$ where σ is the population standard deviation for all marks.

Generic feedback from demonstrators

- Try to be concise
  - What are the key points? (Elevator pitch?)
  - Minimize waffle
  - Be **quantitative** where you can

Further feedback: Blackboard DLM “Scientific Writing”

The technical bit (see lab handbook)

- Discuss which report to write up with your personal demonstrator, before the end of week 10.
- Students can both write up the same experiment, but bear in mind the strict plagiarism rules. Usually Exp. D is not written up, but it can be.
- You are allowed to do extra work on an experiment if you took data that were not satisfactory, by arrangement – but keep this in perspective.

- Submission deadline: 12:30 on the Friday of week 14, 23.
- **ONLY electronic format (.pdf).**
- Late submission will be penalized.

Plagiarism

- All reports will go through Turnitin.
- Plagiarism is taken very seriously, and the consequences can be bad

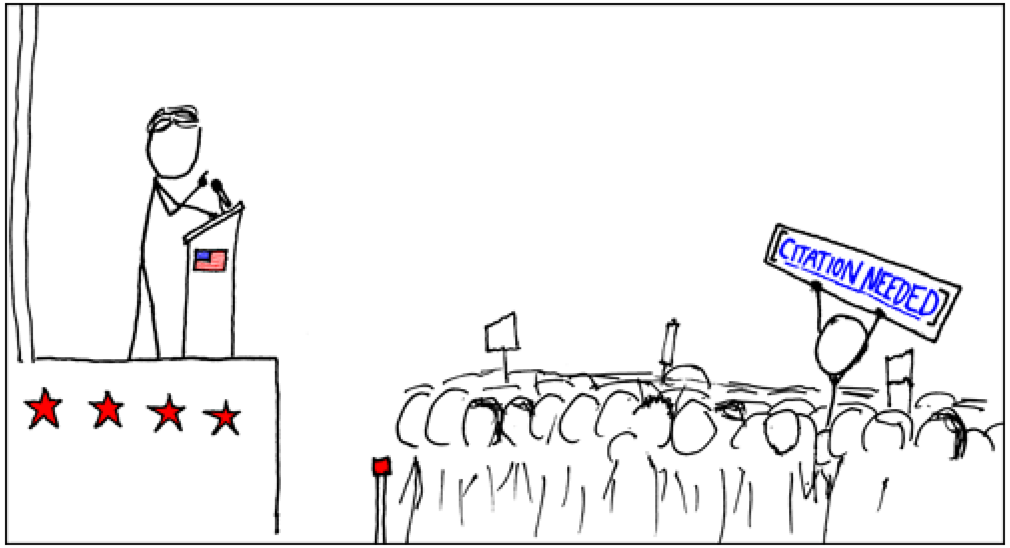
– don't do it!

- If you're not sure if something you are doing is plagiarism: <u>**ASK**</u>.

    www.bristol.ac.uk/students/support/academic-advice/academic-integrity/plagiarism/

- <u>***APPROPRIATE***</u> referencing / citations is crucial.

Relevant xkcd:



xkcd.com

- Writing in your own words makes you think about the subject, and will help you understand it better.
- *Some* quotations are fine…

This is **not** appropriate use of quotations:

"In condensed matter physics, the Fermi surface is an abstract boundary in reciprocal space useful for predicting the thermal, electrical, magnetic, and optical properties of metals, semimetals, and doped semiconductors. The shape of the Fermi surface is derived from the periodicity and symmetry of the crystalline lattice and from the occupation of electronic energy bands. The existence of a Fermi surface is a direct consequence of the Pauli exclusion principle, which allows a maximum of one electron per quantum state."[1] "The Pauli exclusion principle is the quantum mechanical principle that states that two identical fermions (particles with half-integer spin) cannot occupy the same quantum state simultaneously. In the case of electrons in atom, it can be stated as follows: it is impossible for two electrons of a poly-electron atom to have the same values of the four quantum numbers: n, the principal quantum number, ℓ, the angular momentum quantum number, mℓ, the magnetic quantum number, and ms, the spin quantum number. For example, if two electrons reside in the same orbital, and if their n, ℓ, and mℓ values are the same, then their ms must be different, and thus the electrons must have opposite half-integer spins of 1/2 and -1/2. This principle was formulated by Austrian physicist Wolfgang Pauli in 1925 for electrons, and later extended to all fermions with his spin-statistics theorem of 1940." [2]

[1] https://en.wikipedia.org/wiki/Fermi_surface, accessed 11/11/2016.
[2] https://en.wikipedia.org/wiki/Pauli_exclusion_principle, accessed 11/11/2016.

The basic aims of a formal report

Communicate clearly and effectively to your target readership:

- What you have done.
- Why you did it.
- How you did it.
- What conclusions you have reached (quantitative and qualitative).

Q: Is it the same as a scientific paper?

YES

- It should be written with formal scientific language, and logically structured.
- You should aim to format it to a high level with clear figures and diagrams.
- Referencing should be an accepted style.

NO

- You have (probably) not made a new scientific discovery, (although not all published papers report new science).
- You are not writing to an audience of professional scientists.

Structure

- Not fixed: see the Handbook for suggestions, and look at published papers! *Some examples I personally like are: Reviews of Scientific Instruments, American Journal of Physics, Physical Review Letters, Physical Review B, Applied Physics Letters…*
  - *Careful of famous journals like Nature: there are no Abstracts!*

- As a default, “Abstract, Introduction, Methods, Results, Discussion, Conclusion, References”?

Q: Should you write them in this order?

How about the flow?

(formal, nicely formatted, scientifically precise)

- Make it a "story"! How would you explain it to your (scientifically literate / 2nd year Physics UG) friend?

"X is a thing. Experiment Y measures A. Experiment Z measures B and C. Here are some data. End."

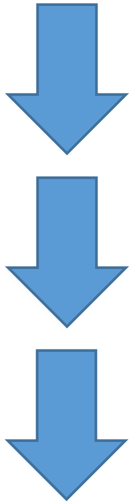
vs

"We wanted to know X, so we did experiments Y and Z, because from these you can learn A, B and C about X. Here is how we did Y, and then Z. Here's the data, and what we can extract. This tells us the following about X. In the future maybe we could make this improvement."

How about the flow?

- This is essentially linear:

"We wanted to know X, so we did experiments Y and Z, because from these you can learn A, B and C about X. Here is how we did Y, and then Z. Here's the data, and what we can extract. This tells us about X – just what we wanted".

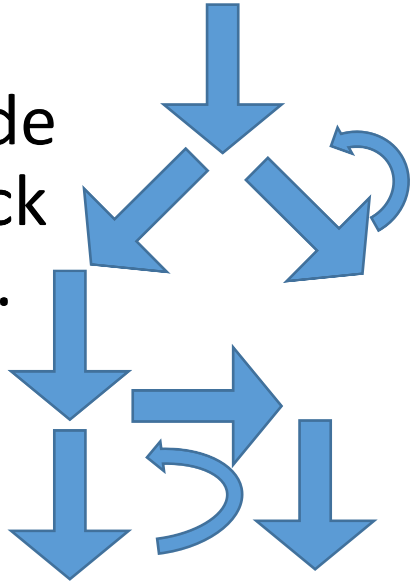


vs

- Non-linear:

"We wanted to know X, so we did expe… Z. Now as a side note Y can also measure D, let'… for a while. Now back to the main point. Here i… , and then Z. Here's the data. We can actually e… g completely different from these data that is inter… hich is E. Let's finish by talking about the original thing you … st track of by now".

Maybe acceptable in a long paper, or a 150 page thesis. Not for a short report.



Contents

What is contained in a formal report that is different from a lab notebook?

- Background history / putting the work in context.
- Need to present results clearly and efficiently, e.g. omit tables of raw results in favour of an appropriate graph.
- Not necessarily chronological
- Discussion – more extended than in lab notebook.
- Abstract.

Background `history’

“Early humans did not know about the existence of x-rays. This all changed in 1895 when Wilhelm Conrad Röntgen, who obtained his PhD thesis at the University of Zurich, discovered a fascinating new type of electromagnetic radiation when he happened to see a fluorescent effect…”

vs

“X-rays are electromagnetic radiation with wavelengths typically in the range 0.01-10 nm, and were discovered in 1895 by Röntgen [1]. X-rays are important in a range of scientific activities, including crystallography, medical imaging and…”

Data presentation

- Obvious things:
  - ***Legible*** label axes, with units.
  - Symbols, or lines?
  - Legend?
  - Error bars (or too small to see? – say that).
  - Informative caption (title ***not*** needed).
- How big should a figure be? A straight line plot with 4 points probably does not need ½ page.
- How many figures showing the same type of data?
- Do you need to show raw data?
- Line is: "a guide to the eye / the best fit straight line to the data / theoretical prediction".

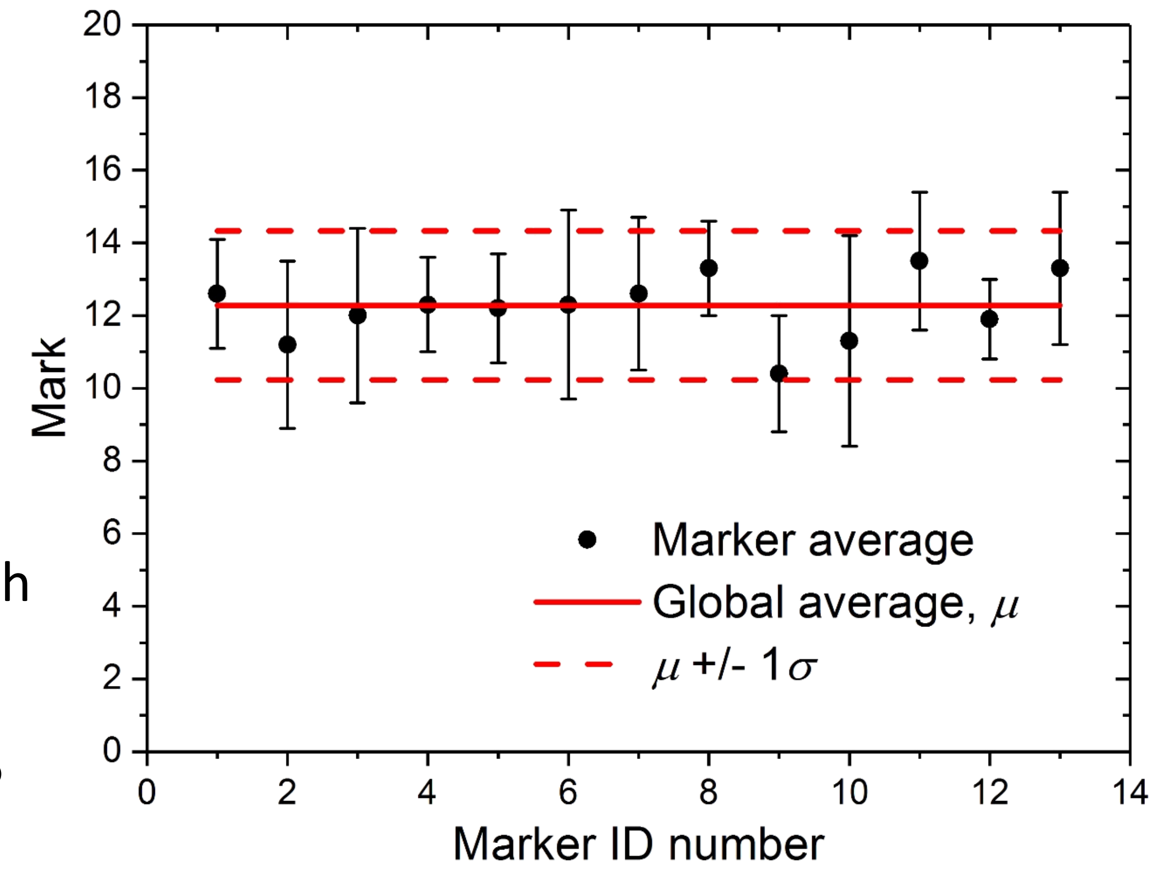
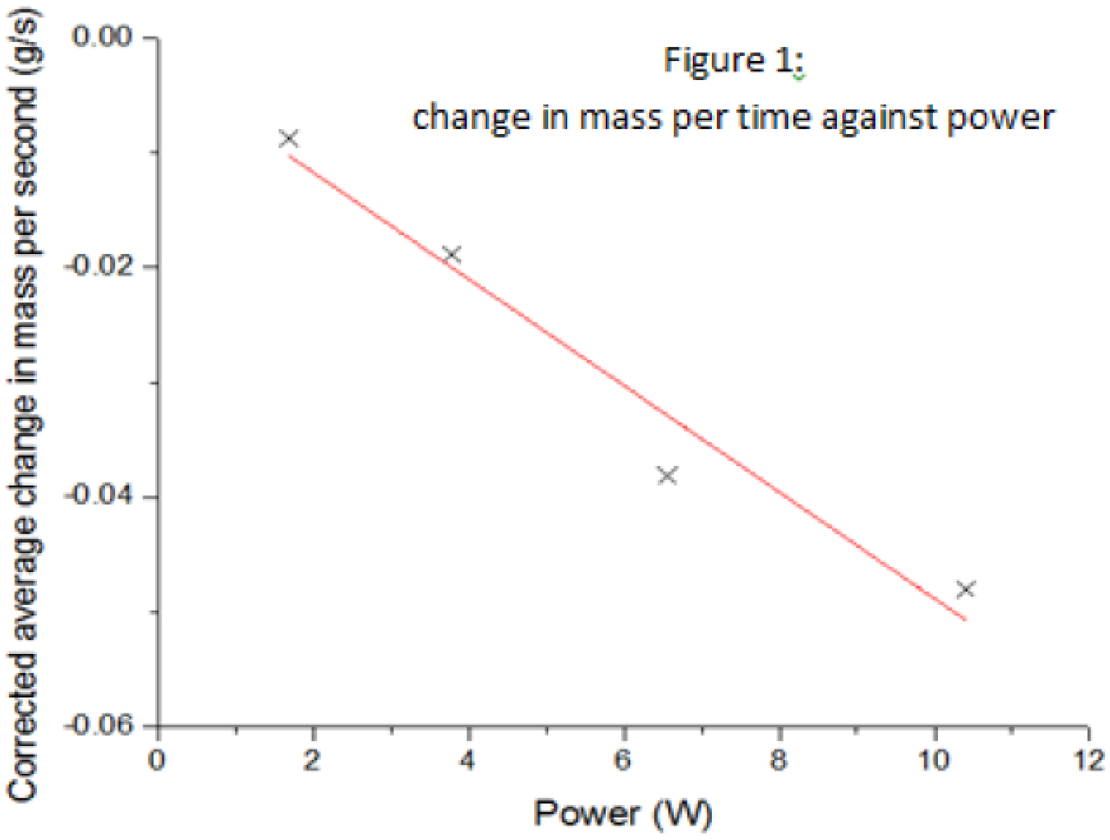


Figure 1: Average mark versus marker (left) and experiment (right). Error bars are the population standard deviation for each marker or experiment. Solid lines show the global average (μ) for all marks. Dashed lines are $\mu \pm 1\sigma$ where σ is the population standard deviation for all marks. Error bar for

5.) Results

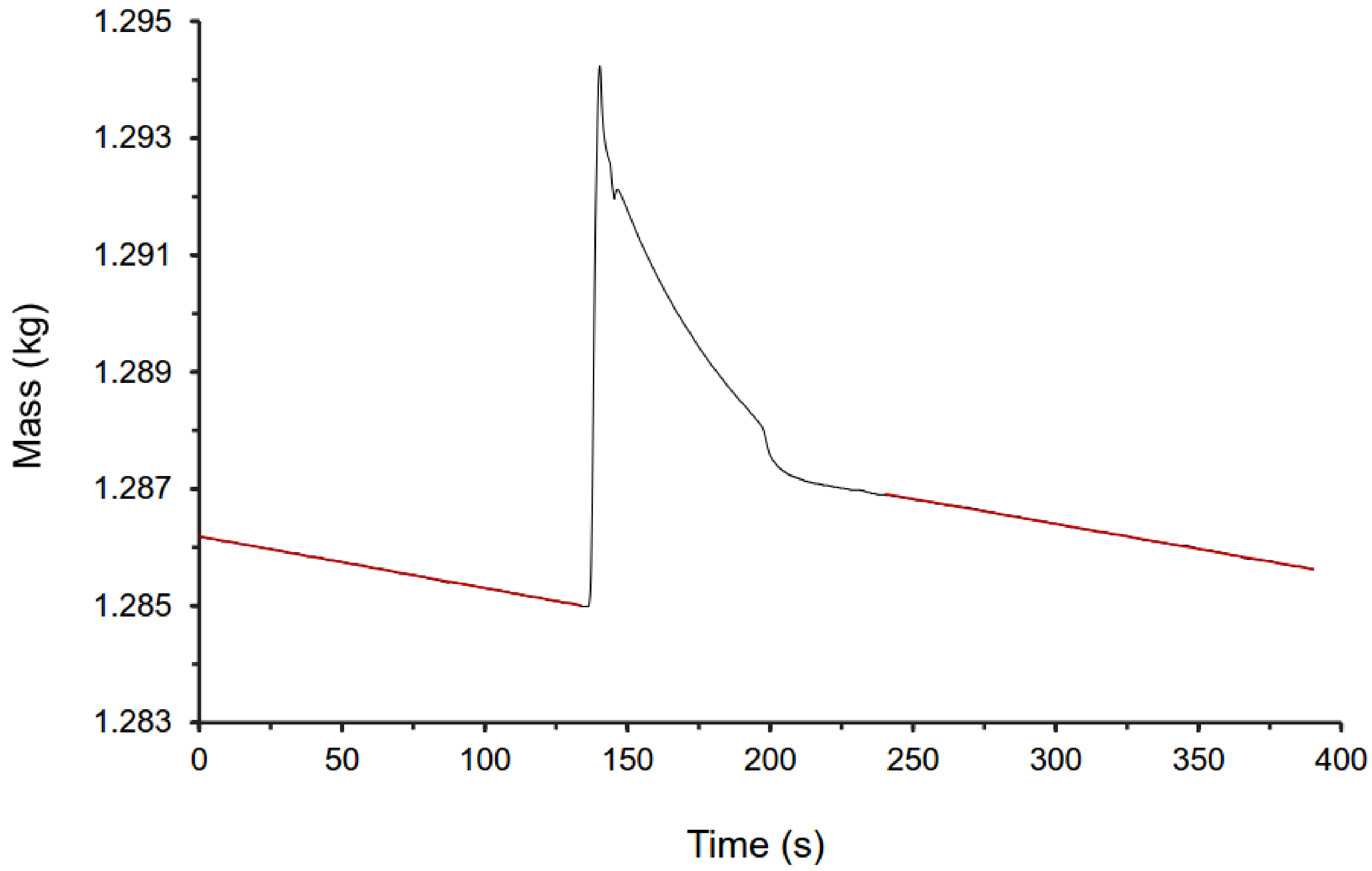
Below, figure 2 shows the graph of change in mass per second against the power of the heating coil.



GOOD POINTS

BAD POINTS

GOOD POINTS



BAD POINTS

Figure 4. Graph of change in mass over time when cooling the aluminium sample (mass 8.312 ± 0.001 g) from (22.3 ± 0.2) °C to (-190.3 ± 0.2) °C. Least-squares linear regression lines have been fitted to the data before submersion and after the rate of change reached the steady background level; these have intercepts at (1286.188 ± 0.001) g and (1288.971 ± 0.003) g respectively.

- Minimize white space, (careful with LaTeX).

Discussion

This is the best opportunity to show that you can think independently, critically, and beyond the confines of the script.

- Explain the data and what solid conclusions you can draw.
- **Compare to the literature**.
- Explain sources of error and limitations of the experiment, and possible ways to fix them / improve (can be things that could have been implemented, or new ways to change the set-up).

Real student report:

> Another large source of error could be in the rate of change of mass due to background heat transfer. When correcting for the background heat transfer it was assumed that the background rate of change of mass was constant, however figure 2 shows that the rate actually varied considerably with time and so the correction is inaccurate.

The abstract

The first thing the marker will read… pretty important!

What should it be:

- A concise summary of the experiments carried out.
- It should contain key findings and any important numerical values derived.
- If possible compare them to previous studies / point out problems.

Several fully functional programmable voltage standard chips, each having a total of 32,768 Nb–PdAu–Nb Josephson junctions, have been fabricated and tested. The chips are based on a new design that provides fast programmability (1 μs) between voltages and stable voltage operation from −1 to +1 V. A comparison of the new standard with a conventional Josephson voltage standard is in agreement to 0.5±1.1 parts in 10^9. We demonstrate the utility of this standard by measuring the linearity of a digital voltmeter.

Benz *et al.*, Appl. Phys. Lett. **71**, 1866 (1997)

Here are two real 2nd year abstracts for experiment L (Latent Heat):

These experiments were performed in order to calculate the specific heat capacities of various solids. They were performed using the latent heat calorimeter method, using liquid nigrogen as the medium. This required the latent heat of vaporisation of nitrogen to first be calculated. It was found to be 195.325±4.619kJ/kg. As the accepted value is 199J/g[1], this lies within the error calculated here.

Using this value, the specific heat capacities of Carbon, Zinc, Copper, Aluminium and Lead were found. There were found starting at both room temperature and from the temperature of dry ice. These results were less accurate than the latent heat value, and are discussed in this report.

A liquid nitrogen calorimeter consisting of a Dewar flask, electric heater and electronic balance has been used to measure the latent heat of vapourization of nitrogen and consequently the specific heat capacities of aluminium, copper, graphite, zinc and lead over the temperature ranges beginning at room temperature or the melting point of dry ice down to the boiling point of nitrogen. The latent heat of vapourization of nitrogen was measured as (236 ± 3) $kJkg^{-1}$, which is considerably higher than the expected value of 200 $kJkg^{-1}$. Possible causes of this discrepancy include a high rate of heat transfer from the surroundings to the nitrogen and unreliable measurements of the rate of heat transfer from the heater. The specific heat capacity measurements suffered from large systematic errors causing most of the results to be outside of the range of expected values. Several possible sources of error have been identified and corresponding improvements have been suggested.

Final comments on language

The more you read scientific papers, the more you will understand how standard scientific language works.

Generally:

- Typically stay in the passive voice “The heat capacity was measured.”.
- Don’t use long convoluted sentences – this is not a work of literature.
- Be precise: “The error on the data was small.” Small relative to what?

… but make it understandable.

Your brain is good at filling in the gaps: what you read is often not what is on the page, it's what you 'know' you wrote. One way to avoid this issue is to wait several days (or longer) and read with "fresh eyes".

PROOF READ AND SPELL CHECK – give yourself time to do this.

Print it out full size to check that figures / diagrams are big enough

Remember most spell checkers only pick up words that are spelt wrong, not the wrong (correctly spelled) words. If you use LaTeX be careful since spell checkers are typically not as strong.

Good rule of thumb: all fonts in the figures should be comparable to the main text.

Questions?

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