How to Write Physics and Engineering

How to Write Physics and Engineering

Lab Reports, Derivations, Design Documents, and Your Final-Year Project

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To everyone who did the experiment properly
and lost the marks in the write-up.

Contents

Preface

The experiment worked.

You set it up carefully, you took the readings, the numbers came out close to the accepted value, and you understood what was happening the whole way through. Then the report came back at 58%, with comments about the graph axes and something about your discussion being descriptive.

That's the gap this book closes, and it's a wide one. In most physics and engineering degrees, a substantial share of your mark comes from documents rather than from lab technique or exam performance, and almost nobody is taught how to write them. You get a template, a page limit, and a deadline.

So students learn report writing by inference, from marks and scribbled comments, over three years, badly.

The strange part is how mechanical the fixes are. Reports lose marks in a small number of predictable places: a results section that argues, a discussion that narrates, an uncertainty quoted to four significant figures, a graph with unlabelled axes, a method that reads like a diary. Each has a rule, each rule takes about a minute to apply, and none of them requires you to understand the physics any better than you already do.

This book is those rules, plus the structures that carry them.

A word on who it's for. It's written for the physics or engineering undergraduate writing a lab report this week, and it stays useful through the design report in year two, the group project in year three, and the final-year thesis. The last part of the book is about documents that get written in industry too: specifications, technical memos, and the executive summary that somebody senior will read instead of your report.

Both subjects are here on purpose. A physicist's lab report and an engineer's test report are the same document with different vocabulary, they're marked on the same things, and the differences that do matter get their own sections.

Two honest warnings.

This book won't make a bad experiment into a good report. If the data are wrong and you don't know why, no amount of structure will rescue it, and the chapter on discussion sections will tell you what to write instead of pretending.

And it will ask you to write less than you currently do. Most student reports are too long, and length is doing the opposite of what students hope: it buries the two paragraphs the marker was looking for. A shorter report that answers the brief beats a longer one every time, and about a third of this book is really about deciding what to leave out.

Let's start with the person who has to read the thing.

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Part I

What a Report Is For

1

The Reader Is a Replicator

Every rule in this book comes from one idea, so it's worth getting it straight before anything else.

A report exists so that somebody who wasn't there can repeat what you did and get the same numbers.

That's it. Not to show you worked hard. Not to prove you understood the theory. Not to fill four pages. Everything that helps a competent stranger reproduce your result belongs in the report, and almost everything else doesn't.

1.1 Three readers, one document

In practice three people read a student report, and they want different things from it.

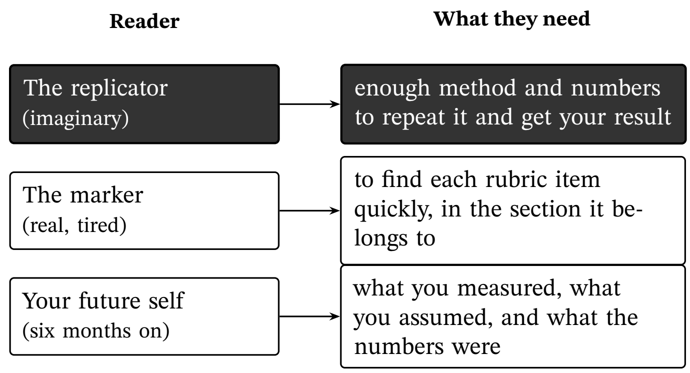

Figure 1.1: Who reads your report and what each of them needs. The replicator is imaginary and the most useful of the three to write for.

Write for the replicator and the other two are satisfied automatically. Write for the marker alone and you produce something that performs knowledge rather than transmitting it, which is the characteristic failure of student reports.

> *The test for any sentence in a report: does it help somebody repeat this work and get the same answer? If not, it's probably decoration, and decoration is where reports get long and marks get buried.*

1.2 What the replicator test throws out

Apply that test honestly and a lot of standard student writing disappears.

Cut	**Why**
"The aim of this experiment was to investigate…and to gain an understanding of…"	the second half isn't an aim, it's a hope
A paragraph explaining what a multimeter is	the replicator owns one
"We then carefully recorded the readings"	carefully does no work; they were recorded or they weren't
The full derivation from a textbook	cite it and quote the result
"This experiment was very interesting"	
A history of the phenomenon	unless the brief asked for it

And it keeps things students routinely leave out:

Keep	**Why**
The exact model of the instrument	a different one has a different resolution
The value you assumed for g	the replicator needs your constants
The room temperature, if it mattered	
Which readings you discarded, and why	otherwise the data can't be reproduced
The version of the software	results move between versions
The uncertainty in every measured quantity	without it the result has no meaning

Notice the asymmetry. What gets cut is mostly words. What gets kept is mostly numbers and specifics, and it's usually shorter than what it replaces.

1.3 One purpose per section

The structure of a report isn't arbitrary. Each section answers exactly one question, and the commonest structural error is answering a question in the wrong place.

Section	**The one question it answers**
Abstract	What did you do and what did you get?
Aim	What question is this work answering?
Theory	What relationship are you testing, and where does it come from?
Method	What would I have to do to repeat this?
Results	What did the instruments say?
Uncertainty	How well do you know those numbers?
Discussion	What do the numbers mean, and do they agree?
Conclusion	What is the answer to the aim?

Put an answer in the wrong section and it usually scores nothing, because the marker is looking for it somewhere else. Interpretation in the results section is the classic case: it's the single most common structural error in student reports, and it costs marks twice, once for the results section being contaminated and once for the discussion looking thin.

FROM THE MARKER'S SIDE

When I mark, I read section by section against the rubric. If your discussion is sitting inside your results, I may credit it and I may not, but I certainly can't credit an empty discussion section, and that's the one carrying the most marks.

1.4 The one-line test

Before you write any section, write down the one question it answers, in the margin or on a scrap. Then, when you've drafted it, check every paragraph against that question.

It takes thirty seconds a section and it prevents most of Part II's problems before they happen.

Do that for a whole report and something else falls out: you'll find paragraphs that answer no question at all. Those are the paragraphs that made your report long, and cutting them is free.

1.5 Physics and engineering, one skill

A quick word on the two subjects, since this book covers both.

The physicist's lab report and the engineer's test report are the same document. Same sections, same rubric logic, same failure modes. Both are asking: what did you measure, how well do you know it, and what does it mean?

Where they differ, genuinely:

- Engineering reports more often carry a *recommendation*, and that recommendation is marked. Physics reports usually stop at the result.
- Engineering documents are more often written to a standard or a specification, and conformance is part of the mark.
- Physics reports weight uncertainty analysis more heavily; engineering weights tolerance, safety factors and fitness for purpose.
- Engineering has more document types: specifications, memos, design reports. Part V covers them.

Everything else in this book applies identically to both, and where a chapter is specific to one, it says so.

BEFORE YOU SUBMIT

Take a report you've already had marked. For each section, write in the margin the one question that section is supposed to answer. Then find one paragraph that answers a different question, or none. That paragraph is where your next report gets shorter and better at the same time.

2

Why Reports Are Marked the Way They Are

Somebody has to mark thirty reports on the same experiment, fairly, in an afternoon. That constraint shapes everything about how your report is assessed, and understanding it is worth more than any amount of polish.

2.1 The rubric behind the red pen

Marking schemes vary, but the weights cluster tightly. Here's what a typical undergraduate lab report rubric actually looks like once you strip the wording.

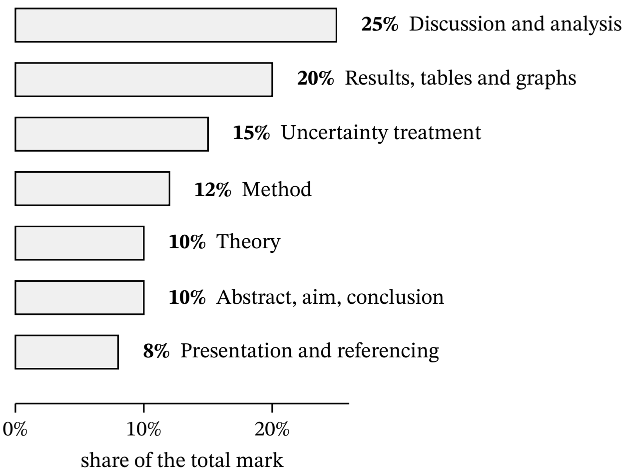

Figure 2.1: A typical lab report rubric. Two thirds of the marks are in three sections, and presentation is worth more than most students believe.

Three things in that chart should change how you allocate your writing time.

Discussion is the biggest single item, and it's the section students write last, fastest, and worst. A report where the discussion is three sentences of "the results agreed reasonably well" has thrown away a quarter of the marks.

Uncertainty is 15%, which is more than method and more than theory. It is also the section most often reduced to one propagation calculation with no words around it.

Presentation is 8%, which sounds small until you notice it's free. Captions, units in table headers, consistent significant figures, a reference list in a single format. None of it requires understanding anything.

2.2 What the marker actually does

Twelve minutes, thirty reports, a rubric with seven rows.

They don't read your report the way you read a novel. They go looking for each rubric item, in the section where it should be, and award or don't.

FROM THE MARKER'S SIDE

I have a rubric on the desk and I fill it in as I go. If I can't find your uncertainty analysis in about fifteen seconds, I'll look in one other place, and then I'll move on. It isn't that I don't care; it's that there are twenty-nine more of these and I owe them the same fifteen seconds.

That has a direct consequence for how you write.

> *Put each rubric item where the rubric expects it, and signpost it with a heading. A report is a document to be searched, not a story to be followed.*

Which is also why the beautifully written report with no headings scores worse than the plainer one with clear ones. Findability is worth marks in a way that elegance isn't.

2.3 Read your own rubric, properly, once

Most departments publish the marking criteria for lab reports and most students never read them.

Do it once, in week two, and do it with a pen:

1. Write the percentage against each section.
2. For each row, find the words that describe full marks. They usually name something specific, like "uncertainties propagated and their effect on the conclusion discussed".
3. Note which rows are about *doing* and which are about *writing*. The writing rows are the ones this book can move quickly.
4. Take your last marked report and score it yourself against the rubric before reading the marker's comments. The gap is instructive.

Fifteen minutes, once a year, and it tells you where the marks in your specific course actually live.

2.4 Length, and why more is worse

Almost every student report is too long, and length actively costs marks.

The mechanism is simple. The marker is searching. Every extra paragraph is another thing to search through, and a rubric item buried in the middle of a long paragraph is a rubric item that might not be found.

Meanwhile there's no row in any rubric for effort.

Typical brief	What it's actually asking for
"no more than 4 pages"	3 pages and a graph, well organised
"a brief report"	2 pages
"a full report"	8–12 pages including figures
"a technical note"	1–2 pages, one figure

If the brief gives a limit, write to about 85% of it. Being at 100% means you've probably padded; being at 60% means you've probably missed a rubric row.

2.5 When there's no rubric

Some courses publish nothing. You can still infer most of it.

Look at the mark split between the lab session and the report. Look at what the demonstrator emphasised. Look at the length limit, which tells you the expected depth. And ask one question, once: *which section carries the most marks?* It's a reasonable question, it isn't asking for anything confidential, and the answer is almost always "the discussion", which most students would not have guessed.

BEFORE YOU SUBMIT

Find your department's lab report marking criteria today. Write the percentage beside each section, then take your last report and mark it yourself against those rows before you look at the actual comments. The two rows where you were most generous to yourself are the two this book should fix first.

3

Where Report Marks Leak

Reports lose marks in the same seven places, term after term, across both subjects.

None of these is "didn't understand the physics". That happens too, and this book can't help with it. These are the losses that happen to students who did the experiment properly.

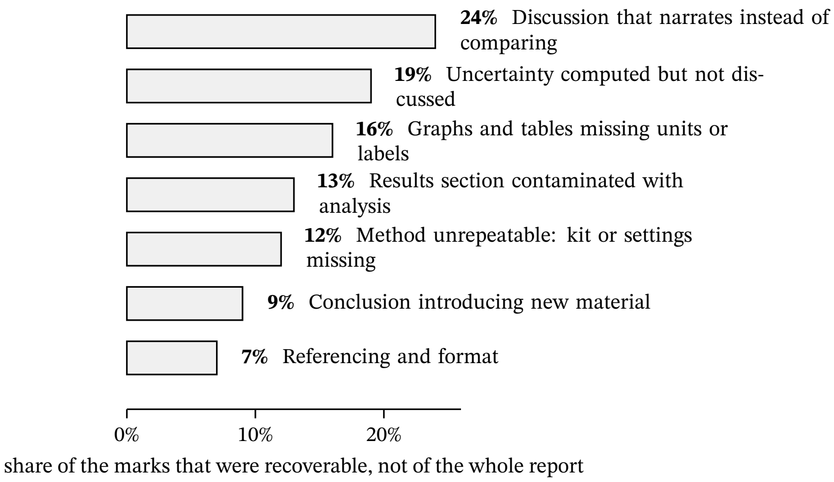

Figure 3.1: The seven leaks, as a share of the recoverable marks lost on a typical student report. The top two are both about the discussion section.

3.1 Leak 1: the discussion narrates

The biggest one, and the hardest to see in your own writing.

A narrating discussion tells the story of the numbers: *the value increased as the current increased, and the graph was approximately linear*. Everything in it is true and none of it is analysis, because it adds nothing the results section didn't already say.

A comparing discussion does four things: it compares your result with an expected value, it says whether the difference is within your uncertainty, it identifies what dominates that uncertainty, and it says what that means for the aim.

Chapter 9 is the full treatment. The one-line version: if your discussion could be written by someone looking only at your graph and not knowing any physics, it's narration.

3.2 Leak 2: uncertainty computed, not discussed

Students do the propagation arithmetic, quote a number, and stop.

The marks are mostly in the sentences around it: which measurement dominates, whether the dominant term could be reduced, and whether your result agrees with the accepted value *given* that uncertainty.

An uncertainty with no discussion is about a third of the available marks on that row. Chapter 8 has the rest.

3.3 Leak 3: graphs and tables

Axes without units. A table without a header row. Three significant figures in one column and six in the next. A graph with no caption, or a caption that says "Graph of results".

This is the purest waste in the whole list, because none of it requires any thought at all. Chapters 12 to 14 are a checklist, and a report that follows them mechanically collects every mark in this row.

3.4 Leak 4: the results section argues

The results section reports what the instruments said. That's all.

The moment it starts explaining why a value came out low, it has become a discussion, and two things break: the results section is no longer a clean record, and the actual discussion section is left repeating itself.

Chapter 7 draws the line precisely, because it's a line students find genuinely unclear.

3.5 Leak 5: the method can't be repeated

The test from Chapter 1, failed.

Usually it fails on specifics: the instrument model isn't given, a setting isn't recorded, the value assumed for a constant isn't stated, or readings were discarded without saying so.

Nobody notices while writing, because you know what you did. The fix is mechanical and lives in Chapter 6.

3.6 Leak 6: the conclusion introduces new material

A conclusion answers the aim, quotes the result with its uncertainty, and stops.

The two ways it goes wrong: it introduces a new idea that appears nowhere else (which always reads as an afterthought), or it repeats the discussion at length. Neither scores.

3.7 Leak 7: referencing and format

Small, and entirely free. One citation style, applied consistently. Figures numbered and referred to by number. Equations numbered if you refer to them. Page numbers.

Nothing here needs a decision, which is why losing marks to it is irritating in a way the other six aren't.

3.8 Audit your own

The same seven-bucket exercise as the other books in this series, applied to reports.

Take your last three marked reports. For every mark lost, assign it to one of the seven leaks, or to an eighth bucket: "the work itself was wrong". Then total them.

Bucket	Marks	
1 Discussion narrates	11	31%
2 Uncertainty not discussed	8	23%
3 Graphs and tables	6	17%
4 Results contaminated	4	11%
5 Method unrepeatable	3	9%
6 Conclusion	2	6%
7 Referencing	1	3%
8 **The work was wrong**	**0**	

That's one real student's three-report audit, and its shape is typical: half the loss in two buckets, and nothing at all in bucket 8.

> *You don't have seven problems. You have two, repeated on every report you've written. Find them once and the rest of this book is a lookup table.*

BEFORE YOU SUBMIT

Do the audit on your last three marked reports. One page, eight buckets, twenty minutes. Write the top two at the front of your lab book. Those two chapters are the ones to read tonight; the rest can wait until you need them.

Part II

The Sections

4

Title, Abstract, and Aim

Three short pieces of text, usually written last, usually written badly, and between them worth about a tenth of the mark.

They're also the first thing the marker reads, which matters more than the percentage suggests.

4.1 The title

A title says what was measured and how. It isn't a topic.

Weak	**Better**
Experiment 4	Measurement of g using a compound pendulum
The Pendulum	Determination of g from the period of a simple pendulum
Ohm's Law	Verification of Ohm's law for a metallic conductor at constant temperature
Beam Deflection	Deflection of a cantilever beam under point loading, compared with Euler–Bernoulli theory

The pattern: *what you measured* plus *by what means*, and where it matters, *under what conditions*.

Note the third one. "At constant temperature" is in the title because the result is false without it, and a title that quietly hides the condition under which the claim holds is doing something worse than being vague.

4.2 The aim

One sentence. It states the question the work answers, and it should be answerable with a number.

BEFORE

> The aim of this experiment was to investigate the behaviour of a cantilever beam and to gain an understanding of the relationship between load and deflection.

Two problems. "Investigate" and "gain an understanding" aren't outcomes; nothing can be checked against them. And there's no quantity.

AFTER

To measure Young's modulus for mild steel from the deflection of a cantilever beam under point loading, and to compare it with the accepted value of 200 GPa.

Now the conclusion has something to answer to, and the discussion has something to compare against. Notice that writing the aim properly determines half the structure of the rest of the report.

> *If your aim contains "investigate", "explore", or "gain an understanding of", it isn't an aim yet. Rewrite it until it names a quantity you will produce a number for.*

4.3 The abstract

The abstract is a miniature of the whole report, in four sentences, and it follows a fixed shape.

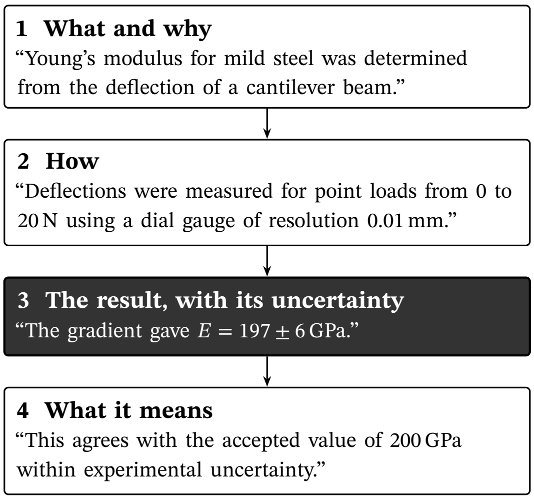

Figure 4.1: The four-sentence abstract. Each sentence has a job, and the numbers belong in sentence three.

Four sentences, about eighty words, and somebody who reads only that knows what you did and what you got.

Three rules that keep it that way:

The number goes in. An abstract without the result is the commonest version of this failure. If a reader has to open the report to find out what you measured, the abstract hasn't done its job.

No references, no figures, no citations. The abstract stands alone.

Write it last. You can't summarise a document you haven't written, and abstracts written first always describe what the student intended to do rather than what they did.

4.4 The one thing students put in and shouldn't

Method detail.

BEFORE

The apparatus was set up as shown in Figure 1. The beam was clamped securely at one end and a hanger was attached at a distance of 300 mm from the clamp. Masses were added in 200 g increments and the dial gauge was zeroed before each reading...

That's a method section, not an abstract. The abstract needs one clause: "deflections were measured for point loads from 0 to 20 N". Everything else lives in Chapter 6's territory.

FROM THE MARKER'S SIDE

An abstract that's a third of a page is nearly always a method section in disguise. The four-sentence version tells me more, and it tells me in fifteen seconds, which is roughly what I have.

4.5 Four abstracts, from four subjects

The shape from Figure 4.1, filled in.

> **Mechanics.** The acceleration due to gravity was determined from the period of a simple pendulum. Periods were measured for lengths from 0.20 to 1.00 m by timing 20 oscillations. A plot of T^2 against L gave $g = 9.80 \pm 0.06\ \mathrm{m\,s^{-2}}$. This agrees with the accepted local value of $9.81\ \mathrm{m\,s^{-2}}$.
>
> **Electronics.** The frequency response of a passive RC low-pass filter was measured. Output amplitude was recorded from 10 Hz to 100 kHz using a signal generator and oscilloscope. The measured -3 dB point was 1.02 ± 0.03 kHz, against a predicted 1.06 kHz from the nominal component values. The 4% difference is consistent with the $\pm 5\%$ capacitor tolerance.
>
> **Materials.** The tensile properties of 6082-T6 aluminium were measured to BS EN ISO 6892-1. Three specimens were tested to failure at a strain rate of $2.5 \times 10^{-4}\ \mathrm{s^{-1}}$. Mean yield strength was 268 ± 7 MPa and mean UTS 312 ± 5 MPa, both within the ranges specified for this temper.
>
> **Thermal.** The thermal conductivity of a copper bar was determined by the Searle's bar method. Steady-state temperatures were recorded at four positions along a lagged bar carrying a measured heat flux. The result, $k = 384 \pm 21\ \mathrm{W\,m^{-1}\,K^{-1}}$, agrees with the accepted value of $401\ \mathrm{W\,m^{-1}\,K^{-1}}$ within uncertainty.

Same four sentences every time: what and why, how, the number, what it means. Once you've written three of these the shape stops requiring thought.

4.6 For engineers: the executive summary

Design reports and industrial documents usually want an executive summary rather than an abstract, and it's a different animal.

An abstract is written for someone who will read the rest. An executive summary is written for someone who won't.

That changes what goes in: the recommendation comes first, the reasoning is compressed, and the cost or the risk is named explicitly. Chapter 19 covers it, and it's worth knowing early that using an abstract where a summary was wanted, or vice versa, is a real and common loss.

BEFORE YOU SUBMIT

Take your last report. Rewrite the aim in one sentence that names a quantity, and rewrite the abstract in exactly four sentences using the shape above. Compare the length with what you submitted. It'll be shorter, and it'll contain more.

5

Theory: The Derivation That Earns Its Place

The theory section has one job: to produce the equation you're going to test, and to make clear where it came from and what it assumes.

That's a much smaller job than most students give it.

5.1 How much derivation is enough

The default student instinct is to reproduce the derivation from the lecture notes in full. It feels safe and it's usually wrong, for a reason that comes straight from Chapter 1: the replicator has the textbook.

The rule:

> *Derive what's specific to your experiment. Cite what's standard. If the derivation appears in the course text in the same form, quote the result and reference it.*

So for a cantilever beam experiment, you don't derive the Euler–Bernoulli equation from first principles. You quote the standard result for end deflection,

$$\delta = \frac{FL^3}{3EI},$$

cite it, and then do the bit that's yours: rearranging it into the form you'll actually plot, and saying what you'll extract from the gradient.

AFTER

For a cantilever of length L with a point load F at the free end, the end deflection is $\delta = FL^3/3EI$ [1], where I is the second moment of area.
Rearranging, $\delta = \left(L^3/3EI\right)F$, so a plot of δ against F is a straight line through the origin with gradient $m = L^3/3EI$. Young's modulus then follows as

$$E = \frac{L^3}{3Im}.$$

For a rectangular section of width b and depth d, $I = bd^3/12$.

Six lines. It quotes the standard result, does the specific rearrangement, names what will be plotted, and gives the expression the experiment will actually evaluate.

5.2 Say what you're plotting, in the theory section

That's the sentence students most often omit, and it's usually worth a mark on its own: *a plot of Y against X gives a straight line of gradient m, from which Q follows as…*

It does three things. It tells the marker you understand what linearising is for. It sets up the results section. And it makes the graph in Part III obvious to construct, because you've already decided what goes on each axis.

1 The standard relationship, quoted and cited

↓

2 The assumptions it rests on, named

↓

3 Rearranged into $Y = mX$, and what you will plot

↓

4 The quantity you extract from the gradient

Figure 5.1: The theory section, as a pipeline. Everything before the last box is quotable; the last two boxes are yours.

5.3 Name the assumptions

Every standard result rests on conditions, and stating them is marked in both subjects. It also gives your discussion section something to work with when the numbers disagree.

For the beam example:

> This expression assumes small deflections, a beam of uniform cross-section, a material within its elastic limit, and a rigid clamp.

One sentence, four assumptions, and every one of them is a candidate explanation if your value of E comes out low. Students who skip this sentence in the theory section end up inventing explanations in the discussion with nothing to anchor them.

FROM THE MARKER'S SIDE

The assumptions line is the cheapest mark in the theory section and perhaps the most useful sentence in the whole report, because it's what the discussion reaches back to when the result disagrees.

5.4 Symbols get defined once, on first use

Every symbol you introduce needs a definition, and the definition belongs where the symbol first appears, not in a glossary at the end.

BEFORE

$\delta = FL^3/3EI$

AFTER

$\delta = FL^3/3EI$, where δ is the end deflection (m), F the applied load (N), L the beam length (m), E Young's modulus (Pa), and I the second moment of area (m^4).

Units in the definitions. It costs one line and it makes the dimensional check in Chapter 11 possible for both you and the marker.

For longer documents, a nomenclature table is appropriate as well as, not instead of, the definitions in the text. Chapter 16 covers when to build one.

5.5 What theory sections are not for

Three things students put here that belong elsewhere or nowhere:

A history of the phenomenon. Unless the brief asks, the origin of Hooke's law is not part of your measurement of a spring constant.

A restatement of the aim. It already has a section.

Every equation you met in the lectures. Only the ones this experiment uses. If an equation appears in the theory section and never again, cut it.

That last test is a good one to run mechanically. Go through your theory section, and for each equation, find where it's used later. If you can't, delete it.

BEFORE YOU SUBMIT

Take the last experiment you did. Write its theory section in under half a page: quote the standard result with a citation, name the assumptions in one sentence, rearrange to $Y = mX$, and state what the gradient gives you. Then compare it with what you actually submitted.

6

Method: Past Passive, and What to Leave Out

The method section is the one with a hard external test. Could a competent stranger repeat this and get your numbers?

Everything else about how it's written follows from that.

6.1 The tense and voice question, settled

Past tense, and usually passive, because what matters is what was done, not who did it.

Not this	This
First we set up the apparatus	The apparatus was set up as in Figure 1
You should then add masses	Masses were added in 200 g increments
Take five readings	Five readings were taken at each load
The beam is clamped	The beam was clamped

Two caveats, because the rule is often taught too rigidly.

Some departments and most engineering employers now prefer active voice with "we". If your brief or house style says so, follow it: "We measured the deflection at five loads" is perfectly good technical writing. What isn't acceptable anywhere is the imperative ("take five readings"), which turns your report into a set of instructions rather than a record.

And don't contort a sentence to stay passive. If the passive version is unreadable, write it actively and move on.

6.2 Specificity is the whole game

The difference between a method that scores and one that doesn't is almost entirely numbers and model names.

BEFORE

> The beam was clamped and masses were added. The deflection was measured with a gauge. Several readings were taken and averaged.

Nothing in that can be repeated. How long was the beam? Which gauge, with what resolution? What masses? How many readings?

AFTER

A mild steel beam of rectangular section (25.0 ± 0.1 mm wide, 6.00 ± 0.05 mm deep) was clamped horizontally, leaving a free length of 300 ± 1 mm.
Point loads were applied at the free end in 200 g increments to a maximum of 2.00 kg, using calibrated slotted masses. End deflection was measured with a dial gauge (Mitutoyo 2046S, resolution 0.01 mm) mounted on a magnetic base and zeroed at zero load.
Three readings were taken at each load, with the load removed and reapplied between readings, and the mean used.

Same experiment. The second one can be repeated tomorrow by somebody who has never seen your bench.

> *Every number in your method is a mark. Dimensions with tolerances, instrument models with resolutions, the range and increment of the independent variable, the number of repeats. Vague verbs are free; vague nouns cost you.*

6.3 What to include, mechanically

Run this list against your draft.

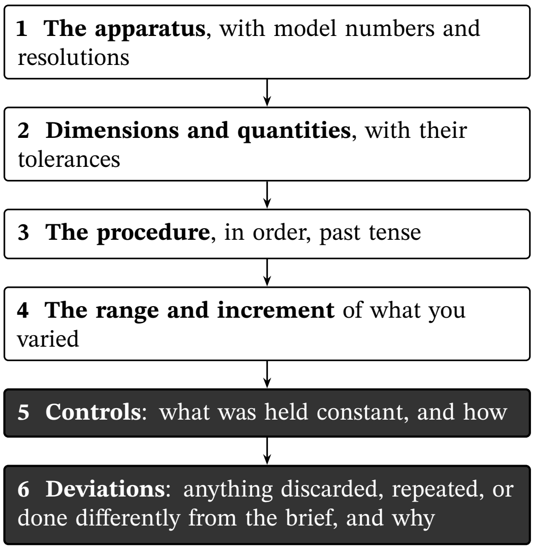

Figure 6.1: The method checklist. Six items, and the last two are the ones students omit.

Item 6 deserves emphasis, because students hide deviations and shouldn't.

If you discarded a reading, say so and say why. If the clamp slipped and you restarted, say so. If you used a 250 g mass because the 200 g was missing, say so. Every one of those is a mark for honest reporting, and concealing them is both a marks loss and, in a professional context, a serious problem.

FROM THE MARKER'S SIDE

A method that says "the third reading at 1.4 kg was discarded because the gauge had been knocked" tells me the student was paying attention. A data set with a suspiciously missing point and no comment tells me something else.

6.4 Diagrams beat paragraphs

One labelled diagram of the apparatus replaces about three hundred words, and it's usually marked.

Rules for it: label every component, mark the dimensions you refer to in the text, give it a figure number and a caption that stands alone (Chapter 14), and refer to it explicitly in the method prose.

Hand-drawn is fine if it's neat and labelled. What isn't fine is a photo of the bench with nothing marked on it, which is decoration rather than information.

6.5 What to leave out

Instructions to the reader. You're recording, not teaching.

Standard technique explanations. Don't explain how to use a micrometer.

Narrative. "We had some difficulty at first but eventually managed to…" belongs in your lab book, not the report. The exception is a genuine deviation under item 6, stated factually.

The brief, copied out. Rewriting the lab script in your own words is not a method section, and markers spot it instantly.

6.6 The method for four kinds of work

The six-item checklist is the same everywhere; what fills it changes.

Bench work	Apparatus with models and resolutions, dimensions with tolerances, procedure in order, range and increment, controls, deviations
Field or site work	The above, plus location, date, conditions (temperature, weather), and anything you couldn't control
Materials testing	The above, plus specimen preparation, dimensions of every specimen, machine and load rate, standard followed
Electrical	The above, plus circuit diagram, component values with tolerances, supply settings, and what was measured where

The row that catches people is field work. Conditions you didn't choose are still part of the method, because the replicator has to know whether they matter. "Measurements were taken between 09:00 and 11:00 on 14 March, air temperature 8–11 °C" is a method sentence.

6.7 Standards and procedures

If your work follows a published test standard, say which, by number, and note any deviation from it.

AFTER

Tensile tests were performed in accordance with BS EN ISO 6892-1, method B, at a strain rate of $0.00025\,\mathrm{s}^{-1}$. Specimen geometry followed the standard's proportional dimensions, except that the parallel length was reduced to 45 mm to suit the available stock.

Two marks in that, and both are typical of engineering assessment: citing the standard, and declaring the deviation from it rather than hoping nobody notices.

6.8 Length

Shorter than you think. A two-page report gets a method of three or four paragraphs; a full report gets a page, including the diagram.

If yours is longer, the usual culprits are copied brief, explained technique, or narrative. All three cut without loss.

BEFORE YOU SUBMIT

Give your last method section to someone on a different course and ask them to list what they'd need to look up before they could repeat your experiment. Every item on their list is a mark you left behind, and the list is usually longer than you expect.

7

Results: The Data, Not the Discussion

The results section reports what the instruments said.

That single sentence resolves nearly every question students have about this section, including the one that costs the most marks.

7.1 The line, drawn precisely

Students find the results/discussion boundary genuinely unclear, so here it is with examples.

Results	**Discussion**
The measured deflections are given in Table 1	The deflections are consistent with linear elastic behaviour
The gradient was $0.402 \pm 0.008\,\mathrm{mm\,N^{-1}}$	The gradient gives $E = 197\,\mathrm{GPa}$, close to the accepted value
The 1.4 kg point lies 0.3 mm above the line	That point is likely affected by the clamp slipping
$E = 197 \pm 6\,\mathrm{GPa}$	The 1.5% deviation is within uncertainty, so the theory is supported

The pattern: results state *what*, discussion states *what it means*. Anything with "because", "suggests", "due to" or "likely" has crossed the line.

> *If a sentence in your results section would still be true if the theory were wrong, it belongs there. If it depends on the theory being right, it belongs in the discussion.*

7.2 What actually goes in

Four things, in this order.

Raw data, in a table. Or a representative sample of it if the data set is large, with the full set in an appendix. Every column headed with a quantity and a unit.

Derived quantities, in the same or a second table. If you converted times to periods, or masses to forces, show the derived column. That column is marked.

The graph. With everything Chapter 13 demands.

The extracted result, with its uncertainty. The gradient, the intercept, and whatever they give you, stated as a clear line.

AFTER

The measured end deflections are given in Table 2 and plotted against applied load in Figure 3. The best-fit line has gradient $m = 0.402 \pm 0.008\,\mathrm{mm\,N^{-1}}$ and intercept $0.01 \pm 0.03\,\mathrm{mm}$.
From $E = L^3/3Im$ with $L = 300 \pm 1\,\mathrm{mm}$ and $I = (4.50 \pm 0.12) \times 10^{-10}\,\mathrm{m^4}$, this gives

$$E = 197 \pm 6\ \mathrm{GPa}.$$

Notice what isn't there. No comparison with the accepted value, no comment on how good the agreement is, no explanation of the scatter. All three are the next chapter's job, and putting them here is leak 4 from Chapter 3.

7.3 Reporting a number properly

Every quantity you report needs four things, and students routinely give two.

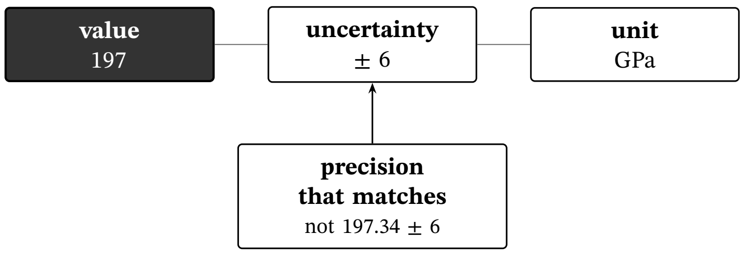

Figure 7.1: Anything you report needs all four. Most student reports give the value and the unit and stop.

The fourth is the one that trips people. If your uncertainty is ± 6 GPa, the value cannot meaningfully be given as 197.34. Round the uncertainty to one significant figure first, then round the value to the same decimal place. Chapter 8 has the rest.

7.4 Sample calculations

Include one worked example of each calculation you did repeatedly, with real numbers, not symbols.

> Sample calculation, first row of Table 2: $F = mg = 0.200 \times 9.81 = 1.962\,\mathrm{N}$, recorded as $1.96\,\mathrm{N}$.

One of each, in the results section or an appendix. Not all of them, which is a page of arithmetic nobody reads, and not none, which loses the mark for showing your working.

7.5 Tables and graphs both, or one?

Both, if the data set is small enough. The table is the record; the graph is the analysis.

For a large data set, put a representative extract in the table, the whole thing in an appendix, and the graph in the body. What you shouldn't do is plot data that appears nowhere in numerical form, because then the replicator can't check your line.

FROM THE MARKER'S SIDE

A graph with no underlying table is a picture of an assertion. I can see the line you drew; I can't see the numbers it was drawn through, and I can't check the two points that look odd.

7.6 Ordering a results section

For a single measurement the order is obvious. For anything with several strands, use this.

1	A sentence saying what was measured and pointing at the table
2	The table
3	A sentence pointing at the graph and stating what it shows
4	The graph
5	The fit parameters, with uncertainties and units
6	The extracted result, displayed
7	Any excluded data, identified with a number

Then repeat 1–7 for each independent strand, under its own subheading. A results section covering three strands with no subheadings is a section a marker has to disentangle, and disentangling costs you.

7.7 Reporting a repeated measurement

Students report means and forget everything else. Four numbers, not one:

AFTER

The period was measured five times at each length. At $L = 0.600\,\mathrm{m}$ the readings were 1.553, 1.559, 1.551, 1.556 and 1.556 s, giving a mean of 1.555 s, a standard deviation of 0.003 s, and a standard error of 0.0014 s. The mean is quoted as $1.555 \pm 0.002\,\mathrm{s}$.

Mean, spread, standard error, and the quoted value. For a table of many repeats you needn't write that paragraph each time; give one worked example and tabulate the rest.

7.8 Anomalies: report, don't explain

If a point is clearly off, say so here, factually, and identify it. Explain it in the discussion.

Results (correct)	**Discussion (correct)**
The reading at 1.4 kg lies 0.3 mm above the best-fit line and was excluded from the fit.	That point was taken immediately after the clamp was re-tightened, which would reduce the effective free length and so the deflection.

And say explicitly whether an excluded point was excluded from the fit. Silently dropping data is the one thing in this chapter that isn't just a marks issue.

BEFORE YOU SUBMIT

Take your last results section and highlight every sentence containing "because", "suggests", "due to", "likely", or "shows that". Move each one to the discussion. Then check whether your results section still contains the four things it needs. Most students find it now needs the fourth: the extracted result stated plainly.

8

Uncertainty: Writing It, Not Just Computing It

Uncertainty is taught as arithmetic and marked as writing.

Students learn to propagate errors, do the propagation correctly, quote a number, and lose most of the marks on that rubric row anyway. This chapter is about the sentences around the number.

8.1 The arithmetic, in one page

The rules you need are short, so here they are, then we can spend the rest of the chapter on what to say about them.

Operation	**Rule**
$c = a + b$ or $a - b$	add *absolute* uncertainties
$c = ab$ or a/b	add *percentage* uncertainties
$c = a^n$	multiply the percentage uncertainty by $\lvert n \rvert$
$c = ka$, k exact	percentage uncertainty unchanged
Reading from a scale	half the smallest division, unless the instrument says otherwise
Repeated readings	the standard error, $s/\sqrt{N}$

Two presentation rules that carry their own marks:

Uncertainty to one significant figure. ± 6, not ± 6.2843.

Value rounded to match. 197 ± 6, never 197.34 ± 6.

> *Round the uncertainty first, to one significant figure. Then round the value to the same decimal place. Doing it the other way round is the commonest presentation error in student physics.*

8.2 Now the sentences, which is where the marks are

A complete uncertainty treatment answers four questions in prose. Most student reports answer none of them.

Sentence two is the one that separates a good report from an average one, and it costs about thirty seconds of thought.

1 What is the uncertainty?
"Combining these gives $E = 197 \pm 6\,\mathrm{GPa}$, a relative uncertainty of 3%."

↓

2 What dominates it?
"The depth measurement dominates: it enters as d^3, so its 0.8% uncertainty contributes 2.4% of the total."

↓

3 Could it be reduced?
"Measuring d with a micrometer rather than callipers would reduce this to about 0.6%."

↓

4 What does it mean for the conclusion?
"The accepted value of 200 GPa lies within one uncertainty of the measured value."

Figure 8.1: The four sentences. The arithmetic produces the number in sentence one; sentences two to four are where the marks are.

8.3 Finding the dominant term

You don't need a full sensitivity analysis. Compute each contribution as a percentage and look at which is biggest.

AFTER

Contributions to the uncertainty in E:

Quantity	**Rel. unc.**	**Contribution**
Depth d (enters as d^3)	0.8%	2.4%
Length L (enters as L^3)	0.33%	1.0%
Gradient m	2.0%	2.0%
Width b	0.4%	0.4%
Total (in quadrature)		**3.4%**

That table is worth several marks on its own, and it makes sentences two and three write themselves: the depth and the gradient dominate, the width is negligible, and improving the callipers is the cheapest gain.

Note the power rule doing visible work. A 0.8% uncertainty on d becomes 2.4% because d enters cubed, which is exactly the sort of observation markers are looking for and students rarely make.

FROM THE MARKER'S SIDE

The single sentence that most improves an average report is the one naming the dominant uncertainty. It shows you understand what limits your result, which is most of what an uncertainty section is testing.

8.4 Agreement, stated properly

There's a right way to say whether your result agrees, and a wrong way that appears in almost every student report.

Weak	Correct
The result was quite close to the accepted value	The accepted value lies within one uncertainty of the measured value
There was a small percentage error of 1.5%	The 1.5% deviation is smaller than the 3% uncertainty, so the values agree
The result was reasonably accurate	The measured and accepted values agree within experimental uncertainty
The error was acceptable	The deviation is 0.5 standard uncertainties

The rule underneath: agreement is a comparison between the *deviation* and the *uncertainty*, not a judgement about how close the numbers look.

And if they don't agree, say that plainly too. A result that sits four uncertainties away from the accepted value is a finding, and the honest report says so and then investigates. Which is the next chapter.

8.5 Systematic versus random

Both get discussed, and they behave differently.

Random uncertainties scatter the points about the line. Repeating reduces them, and the standard error quantifies them.

Systematic uncertainties shift the whole line. Repeating does nothing. A zero-offset on a gauge, a mis-calibrated mass, a consistently mis-measured length.

The practical tell: if your points lie beautifully on a line but the gradient gives a value 8% away from accepted, you have a systematic problem, and no amount of repeating will find it.

Say which kind you think dominates. It's a mark, and it directs the improvement suggestions in your discussion toward things that would actually work.

8.6 Where each uncertainty comes from

Before you can propagate anything, you need a defensible number for each input, and students often guess. Here's where each one actually comes from.

Source	How to get the number
Analogue scale	Half the smallest division, unless the scale is coarse and you can interpolate
Digital display	The last digit, or the manufacturer's stated accuracy if you have it
Manufacturer's spec	Use it: "$\pm$(0.5% + 2 digits)" is more honest than half the last digit
Repeated readings	Standard error $s/\sqrt{N}$, and say what N was
A single reading of a fluctuating quantity	The observed range, halved
Timing by hand	Reaction time, roughly 0.2 s, and it applies twice
A quoted constant	Whatever the source states; if none, the last figure quoted

Two notes worth having.

Half a division is a default, not a law. On a coarse scale you can often read to a fifth of a division, and on a jittery one you can't read to half. Say which you did.

Repeats and resolution are different things. If three repeats give identical readings, your uncertainty isn't zero; it's the instrument resolution. Students often report a standard error of zero and it's never right.

8.7 The words to avoid

"Human error" is not an explanation. It names no mechanism, it can't be quantified, and it appears in almost every weak report. If you mean reaction time in starting a stopwatch, say that, and give it a number.

"Error" used to mean uncertainty. Strictly, error is the difference from the true value (which you don't know); uncertainty is the range you can defend. Most schemes tolerate the loose usage, and using the right one costs nothing.

"Accurate" and **"precise"** are not synonyms. Precise means tightly clustered; accurate means close to the true value. A systematic offset gives you precise and inaccurate, and saying so correctly is marked.

BEFORE YOU SUBMIT

Take your last report's uncertainty section. Add the contributions table, then write the four sentences: the value, what dominates, how it could be reduced, and what it means for agreement. Most students find they had sentence one and none of the others, which is roughly a third of that rubric row.

9

Discussion: Comparison, Not Narration

The biggest section, the most marks, and the one most students write in the last twenty minutes.

It's also the one with the clearest template, which is lucky, because students think of it as the section where you have to be clever and it isn't.

9.1 Narration versus comparison

Here's the test from Chapter 3, in full.

BEFORE

> The graph showed a linear relationship between load and deflection. As the load increased, the deflection also increased. The points fitted the line quite well, although one point was a bit off. The value obtained for Young's modulus was 197 GPa, which is fairly close to the accepted value. The experiment was reasonably successful, although there were some errors which could be reduced by taking more readings.

Every sentence is true. It scores very little, because none of it does anything the results section didn't already do.

Notice what's missing: no number for the agreement, no reference to the uncertainty, no identification of what limited the result, no engagement with the assumptions, and an improvement suggestion ("more readings") that wouldn't have helped, because the limitation was systematic.

AFTER

> The measured value $E = 197 \pm 6$ GPa agrees with the accepted value of 200 GPa for mild steel: the deviation of 1.5% is well within the 3% uncertainty, so the data support the Euler–Bernoulli prediction over this load range.
> The uncertainty is dominated by the beam depth, which enters as d^3; its 0.8% measurement uncertainty contributes 2.4% of the 3.4% total. Measuring d with a micrometer instead of vernier callipers would reduce the overall uncertainty to about 2.5%, and no amount of additional loading repeats would achieve the same, because the depth error is systematic rather than random.
> The intercept, 0.01 ± 0.03 mm, is consistent with zero, as the theory requires for an ideal clamp. A significantly positive intercept would have indicated clamp compliance, and its absence supports the rigid-clamp assumption stated in Section 2.
> The reading at 1.4 kg was excluded from the fit. It was taken immediately after the clamp was re-tightened, which would shorten the effective free length and reduce the

deflection, consistent with the point lying above the line.

Four paragraphs. Each one does a specific job, and the jobs are the same in every report you'll ever write.

9.2 The four-paragraph template

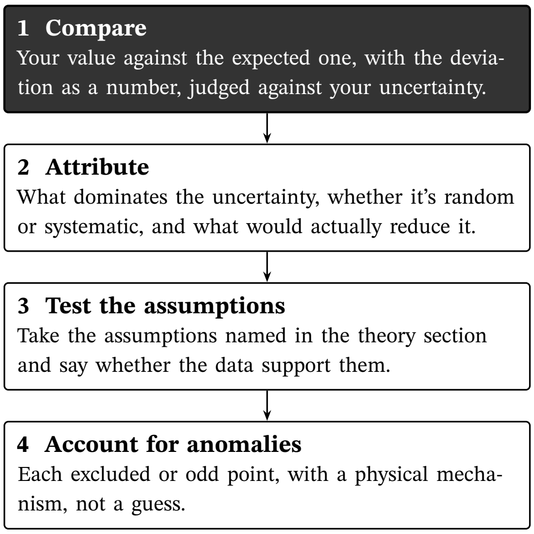

Figure 9.1: The discussion, as four jobs. Nearly every lab report discussion in either subject fits this shape.

Paragraph three is the one almost nobody writes, and it's the cheapest distinction available. You already listed the assumptions in the theory section (Chapter 5); now go back and check each against your data. The intercept tells you about the clamp. The linearity tells you about the elastic limit. Each check is one sentence.

> *Your discussion is a conversation with your own theory section. Every assumption you named there gets a verdict here, and every verdict is a mark.*

9.3 When the result disagrees

Sometimes the numbers are wrong and you don't know why. Students panic and either hide it or blame "human error".

Do neither. A disagreement handled honestly scores far better than a fudged agreement, and the structure is:

1. **State it plainly, with numbers.** "The measured value is $E = 154 \pm 6$ GPa, which is 23% below the accepted value and more than seven uncertainties away. The values do not agree."
2. **Rule out the random.** If the scatter is small, the problem isn't noise, and say so.
3. **Propose specific systematic mechanisms**, and say what each would do to the result, with a sign. "If the free length were 5 mm longer than measured, E would be underestimated by about 5%."
4. **Say what would test it.** "Re-measuring L from the clamp face rather than the clamp body would resolve this."

Note step 3's discipline: every proposed cause must have a *direction*. A mechanism that would push your result the wrong way isn't an explanation, and checking the sign is what distinguishes real analysis from a list of things that might have gone wrong.

FROM THE MARKER'S SIDE

A report that says "these do not agree, here are three candidate mechanisms, two of which would move the result in the right direction, and here's how to test them" gets close to full marks on this row even though the experiment failed. That's what the row is for.

9.4 Comparing with literature, properly

Many discussions have to compare against published values rather than a single accepted constant, and the comparison has its own rules.

Name the source and the conditions. A published value of thermal conductivity was measured on a particular alloy at a particular temperature. If yours differs, that may be why, and saying so is analysis.

Compare uncertainties, not just values. If the literature value carries $\pm 2\%$ and yours carries $\pm 6\%$, the agreement test uses both.

Prefer a range to a single number where the literature disagrees. "Published values range from 195 to 205 GPa depending on carbon content [2, 3]; our value of 197 GPa lies within that range" is stronger than picking one and matching it.

Weak	Better
The accepted value is 200 GPa	Mild steel is quoted at 200 GPa [2], measured on a 0.2% carbon alloy at 20 °C
Our value was slightly lower	Our value is 1.5% lower, well inside the combined uncertainty of both measurements
This agrees with the literature	This lies within the 195–205 GPa range reported for this material class

9.5 Improvement suggestions that aren't useless

Almost every student report ends with the same three: take more readings, be more careful, use better equipment.

The first is only right if your uncertainty is random and dominated by scatter. The second isn't a suggestion. The third names no equipment.

A useful improvement names the measurement, the instrument, the expected gain, and ideally the cost.

Useless	Marked
Take more readings	Repeats would not help: the dominant term is systematic
Use better equipment	A micrometer on d would cut the dominant 2.4% contribution to about 0.6%
Be more careful	Clamping the beam against a machined stop would fix L to ± 0.2 mm
Reduce human error	Timing 20 oscillations rather than one reduces the reaction-time contribution twentyfold

9.6 Length and order

The discussion is usually the longest section, and it should be. On a four-page report, expect a page.

Order matters: comparison first. The marker is looking for whether you got the right answer and whether you know it, and burying that under three paragraphs of error discussion is a common self-inflicted wound.

BEFORE YOU SUBMIT

Take your last discussion section and label each paragraph 1, 2, 3, or 4 against the template. Most students find they have one and a half paragraphs, both of type 1, and nothing of type 3. Write the missing paragraph 3 now, from the assumptions in your own theory section: it's three sentences and it's the cheapest improvement in this book.

10

Conclusion, and What It May Not Contain

Short, and constrained in a way students find surprising.

A conclusion answers the aim. It quotes the result with its uncertainty. It states whether that answers the question. Then it stops.

10.1 The shape

AFTER

> Young's modulus for the mild steel beam was determined as $E = 197 \pm 6\,\text{GPa}$ from the gradient of deflection against load. This agrees with the accepted value of 200 GPa within experimental uncertainty, supporting the Euler–Bernoulli prediction over the load range tested. The uncertainty is dominated by the measurement of beam depth.

Three sentences. The result, the verdict against the aim, and the limiting factor.

For a longer report, four or five sentences, and for an engineering report one more: the recommendation. Nothing beyond that.

> *A conclusion contains nothing that hasn't already appeared. If a reader meets an idea for the first time in your conclusion, it's in the wrong place, and it reads as an afterthought whether or not it's a good idea.*

10.2 The four things that don't belong

New material. The commonest failure. A fresh explanation, a new source of error, a suggestion that appears nowhere else. If it's worth saying, it belongs in the discussion, and moving it there costs nothing.

The discussion again, at length. A conclusion that restates every paragraph of the discussion adds nothing and wastes the reader's last impression.

Hedging. "The experiment was fairly successful and the results were reasonably good." Either the values agree within uncertainty or they don't. Say which.

Method detail. "By clamping the beam and adding masses in 200 g increments, we found…" The method has a section.

10.3 Answering the aim, literally

The cleanest way to write a conclusion is to put your aim next to it and check that one answers the other.

Aim	**Conclusion**
To measure E for mild steel and compare with the accepted value	$E = 197 \pm 6$ GPa, agreeing with 200 GPa within uncertainty
To determine whether the period is independent of amplitude below 10°	The period varied by less than 0.4% over 2° to 10°, consistent with independence at this precision
To select a material for the bracket	Aluminium 6082-T6 is recommended; it meets the load case with a safety factor of 2.4 at 40% of the mass of the steel option

Each conclusion answers its aim in the same terms the aim used. If yours doesn't, one of the two is wrong, and it's usually the aim.

FROM THE MARKER'S SIDE

I read the aim and the conclusion together, deliberately, before anything else. If they don't line up, I know before I've read a word of the middle that something structural has gone wrong.

10.4 For engineers: the recommendation

Engineering conclusions usually carry a recommendation, and it's marked separately from the result.

A recommendation names the option, the reason, and the condition under which it holds.

BEFORE

Aluminium would probably be the best choice for this application.

AFTER

Aluminium 6082-T6 is recommended for the bracket. It meets the 4 kN load case with a safety factor of 2.4 at 38% of the mass of the mild steel alternative, and its cost premium of £8 per unit is recovered in freight within 300 units. This assumes the operating temperature stays below 80 °C; above that, the steel option should be revisited.

Option, quantified justification, and the boundary of validity. That last clause is what distinguishes an engineering recommendation from an opinion, and it's marked.

10.5 Length, per document type

Document	Conclusion
Two-page lab report	2–3 sentences
Full lab report	one short paragraph
Design report	a paragraph plus a recommendation
Final-year project	half a page, plus separate further-work section

Note the last row. In a long document, "further work" is its own section and doesn't belong inside the conclusion, which keeps the conclusion clean and gives the further-work ideas room to be specific.

BEFORE YOU SUBMIT

Put your aim and your conclusion side by side on one page, with nothing else. Do they use the same words for the same quantity? Does the conclusion contain a number the aim asked for? Does it contain anything that appears nowhere else in the report? Ten minutes, and it usually finds one of the three failures above.

Part III

Numbers, Tables, and Figures

11

Units, Significant Figures, and Notation

Free marks, lost constantly.

Nothing in this chapter requires you to understand anything. It's a set of conventions, and applying them mechanically collects every mark on the presentation row and several on the results row.

11.1 Units

A number without a unit is not a result. It's the single most common presentation error in both subjects, and it's usually worth a mark per occurrence.

One space between number and unit. 4.7 kN, not 4.7kN. The exception is degrees: 30°, no space.

Upright, not italic. Quantities are italic, units are upright: $m = 4.7\,\mathrm{kg}$. In LaTeX that's the difference between `$4.7 kg$` and `4.7\,kg`, and the first one is wrong.

Capitals follow the person. newton but N, pascal but Pa, kelvin but K. And it's "5 K", never "5 °K".

Compound units with a middle dot or a space, and negative powers. $\mathrm{m\,s^{-1}}$ rather than m/s in formal work; both are acceptable in most courses, but never mix them in one document, and never write things like m/s/s.

Wrong	Right	Why
4.7kN	4.7 kN	space
5 °K	5 K	kelvin takes no degree
10 Kg	10 kg	lower-case k, upper-case G only for giga
9.81 m/s/s	$9.81\,\mathrm{m\,s^{-2}}$	stacked division
4.7 *kg*	4.7 kg	units are upright
20 Mhz	20 MHz	hertz is a person

11.2 Significant figures

Four rules, in order of how often they're broken.

Match the data. The result carries the precision of the least precise input. Three-figure data gives a three-figure answer, whatever the calculator says.

Match the uncertainty. If you quote an uncertainty, the value's precision follows from it, as in Chapter 8.

Never round mid-calculation. Carry full precision through and round once, at the end.

Obey explicit instructions exactly. "To 2 decimal places" and "to 3 significant figures" are different requests.

FROM THE MARKER'S SIDE

An answer given as 197.34281 GPa tells me the student pressed equals and copied the display. It's a small thing and it colours how I read the rest, because it suggests nobody looked at the number and asked whether it made sense.

11.3 Prefixes: convert first, always

The rule that eliminates the single highest-volume error in engineering reports.

> *Convert every quantity to base SI units before it enters a formula. Do the whole calculation in metres, kilograms, seconds, then convert back at the end if the answer wants a prefix.*

Mixed prefixes mid-calculation, millimetres in one term and metres in another, produce answers out by exactly 10^3 or 10^6, and they're distressingly hard to spot afterwards because every individual line looks right.

Prefix	Factor	Watch for
G	10^9	GPa in materials problems
M	10^6	MPa, MHz; capital M
k	10^3	kN, kg; lower-case k
m	10^{-3}	mm; the classic 10^3 error
μ	10^{-6}	μm, μF; not "u" in formal work
n	10^{-9}	

Note the m/M distinction. Writing MM or mm carelessly is the difference between a millimetre and, well, nothing sensible, and it happens in handwritten work constantly.

11.4 Notation for numbers

Scientific notation for very large and very small. 4.50×10^{-10} m^4, not 0.000000000450.

A leading zero. 0.45, never .45.

Thousands separated by a thin space or not at all, never a comma in technical work: 12 500 or 12500. Commas mean decimal points in much of the world, and technical documents avoid the ambiguity.

Ranges with "to" when units are involved. "5 mm to 20 mm", because "5–20 mm" can read as a subtraction.

11.5 Symbols and italics

Thing	Style	Example
Variable	italic	E, F, δ
Unit	upright	kg, Pa, N
Chemical element	upright	Fe, Al
Function name	upright	sin, log, exp
Constant with a fixed value	italic	g, c, h
Subscript that's a label	upright	F_{max}, T_{room}
Subscript that's a variable	italic	x_i, a_n

The last two rows catch nearly everyone. A subscript that stands for a word is upright; a subscript that stands for a number or index is italic. It's a small distinction and it's the mark of someone who has been taught properly.

11.6 Consistency beats correctness

One caveat on all of the above.

Departments and employers have house styles, and they differ. Some want m/s, some want $\mathrm{m\,s^{-1}}$. Some want SI throughout, some tolerate mixed units in mechanical work.

Where your brief specifies, follow the brief. Where it doesn't, pick one convention and use it in every table, figure and sentence in the document. A report that's internally consistent reads as competent even where the choice differs from the marker's preference; one that switches between conventions on adjacent pages doesn't.

BEFORE YOU SUBMIT

Take your last report and check three things only: every numerical answer has a unit, every table header has a unit, and no answer has more figures than its inputs justify. Count the failures. For most students it's between four and ten, and every one of them was a free mark.

12

Tables That Get Marked

A table is a piece of apparatus for transmitting numbers. It has rules, they're short, and following them is worth more marks than the effort involved.

12.1 The anatomy

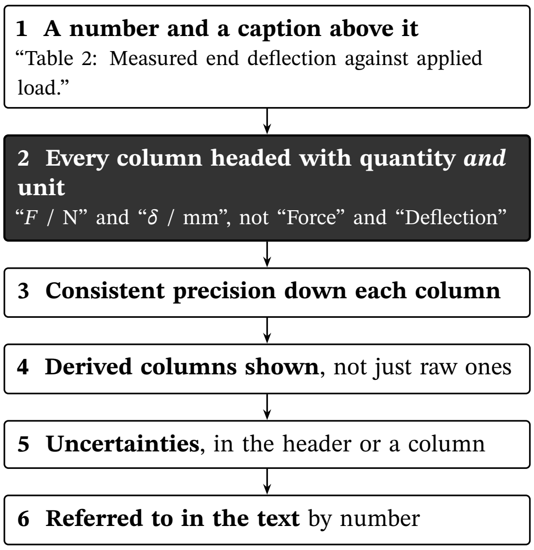

Figure 12.1: A table that scores. Six features, and students routinely supply two.

Item 2 is the one that costs marks most often, and the "/" notation is worth understanding rather than copying. The column header "F / N" means the entries are the quantity divided by the unit, so they're pure numbers. That's why the cells contain 1.96 rather than 1.96 N: the unit has already been divided out in the header.

It's a small piece of convention that makes a table much cleaner, and using it correctly signals that somebody taught you.

12.2 Before and after

BEFORE

Mass	Force	Deflection
200g	1.96	0.8mm
400 g	3.92 N	1.61
600g	5.886	2.4 mm
800	7.85	3.2124

Units in three different places, inconsistent precision, no caption, no uncertainties, and a mass column that's raw data doing no work.

AFTER

Table 2: Measured end deflection against applied load for the mild steel cantilever ($L = 300 \pm 1$ mm). Each deflection is the mean of three readings.

m / g	F / N	δ / mm
200	1.96	0.80
400	3.92	1.61
600	5.89	2.40
800	7.85	3.21

Uncertainties: ± 0.01 N in F, ± 0.02 mm in δ.

Same data. Units in the headers only, consistent two-decimal precision, right-aligned numbers, a caption that stands alone, the conditions stated, and the uncertainties given once rather than repeated in every cell.

12.3 Rules that aren't obvious

Right-align numbers, on the decimal point. Left-aligned numeric columns are hard to compare at a glance, which is the entire purpose of a table.

No vertical rules. Booktabs style: a rule at the top, one under the header, one at the bottom, and nothing else. Vertical lines and full grids are a spreadsheet habit and they make tables harder to read, not easier.

Caption above the table, below the figure. That's the convention in almost every technical style guide, and getting it backwards is a small tell.

Uncertainties once, not per cell. If every reading has the same uncertainty, say so in the caption or a footnote. If they differ, give a column.

Don't split a table across a page break if you can avoid it. If you can't, repeat the header row.

12.4 When to use a table and when not to

Use a table	Use a graph
The reader needs the actual values	The reader needs the trend
Fewer than about 20 rows	Many points
Values will be re-used or checked	The relationship is the point
Categories rather than a continuum	A continuous independent variable

Often you want both, and that's fine: the table is the record, the graph is the analysis. What you shouldn't do is present the same data twice in two graphs, or plot data that appears nowhere numerically.

> *Never present the same numbers twice in the same form. A table and a graph of the same data are complementary; two graphs of it are padding, and padding is Chapter 2's length*

> *problem.*

12.5 Three tables that carry marks

Beyond the data table, three specific tables appear again and again and each is worth building deliberately.

The parameters table. Every constant your analysis used, with its value, unit and source. It makes the work reproducible and it stops constants being scattered through the prose where nobody can find them.

AFTER

Quantity	Value	Source
g	9.81 m s^{-2}	standard, local latitude
E (accepted)	200 GPa	[2], 0.2% C steel
ρ	7850 kg m^{-3}	[2]

The uncertainty contributions table. From Chapter 8. Quantity, relative uncertainty, contribution, total.

The comparison table. Your value against expected values, with uncertainties on both and the deviation in the final column. It does the first paragraph of your discussion in a form the marker can check at a glance.

Source	E / GPa	Unc.	Deviation
This work	197	$\pm$ 6	—
Ref. [2]	200	$\pm$ 4	1.5%
Ref. [3]	205	$\pm$ 8	3.9%

12.6 Large data sets

If you have two hundred rows, don't put them in the body.

Put a representative extract in the body, clearly labelled as an extract, and the full set in an appendix. Then reference the appendix from the results section.

For very large data sets, or anything machine-logged, say where the data lives: "the full data set (1 024 points) is included as `beam_data.csv` in the submitted archive". Increasingly that's expected, and it's what the replicator test demands.

FROM THE MARKER'S SIDE

An appendix full of raw numbers is fine and often good. What isn't fine is a body section where two pages of table have pushed the analysis onto page six, because at that point the document has stopped being organised for its reader.

BEFORE YOU SUBMIT

Take the last table you submitted and rebuild it against the six-item anatomy: caption above, units in the headers only, consistent precision, derived columns, uncertainties stated once, referenced from the text. It takes about five minutes, and it'll be the fastest marks you recover from this book.

13

Graph Forensics

Graphs carry more marks per square centimetre than anything else in a report, and they're the thing students spend the least care on.

This chapter is twelve graphs that lose marks, and what each one should have been.

13.1 The checklist first

Every graph in every report, both subjects, gets checked against these seven.

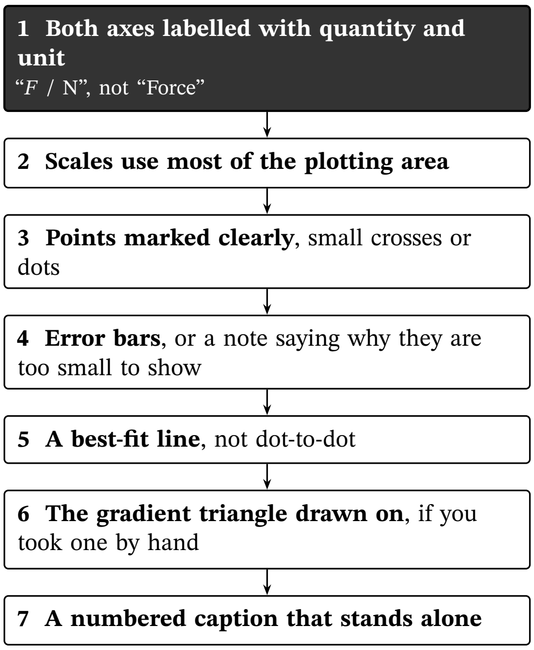

Figure 13.1: The seven-point graph check. Six of the seven require no physics at all.

13.2 The twelve

1. Axes labelled with words, not quantities and units. "Time" instead of "t / s". Half a mark each, twice per graph, on every graph in the report.

2. A scale that uses a third of the paper. Points crammed into one corner because the axes start at zero when the data starts at 40. If zero isn't meaningful, don't include it, and say so if the suppressed zero could mislead.

3. Dot-to-dot. Joining consecutive points with straight segments instead of fitting a line. It says you don't know what the graph is for: the line is a model, not a path through the data.

4. A line forced through the origin. Only force it if the theory requires it, and if the theory does require it and your data won't allow it, that's a finding for the discussion, not something to hide.

5. No error bars, and no explanation. If they're smaller than the marker size, write exactly that in the caption. Silence reads as forgetting.

6. A gradient taken from two data points. The whole reason for fitting a line is to average the scatter. Use two points *on the line*, far apart.

7. A gradient triangle spanning a quarter of the line. It multiplies your reading error by four. Use the largest triangle the line allows, and draw it on.

8. The gradient quoted without units. A gradient is a physical quantity: $\mathrm{mm\,N^{-1}}$, $\mathrm{s^2\,m^{-1}}$. Its units are how you know which quantity it gives you.

9. Plotting the wrong thing. T against L when the theory says T^2 against L is linear. If the brief says "plot a suitable straight-line graph", linearising *is* the question.

10. Excel defaults. Grey plot background, a legend for a single series, a chart title duplicating the caption, and a trendline whose equation is quoted to six figures. Every one of those is worth removing.

11. A caption that says nothing. "Figure 3: Graph of results." Chapter 14 is entirely about this.

12. A graph nobody refers to. If the text never says "see Figure 3", the figure is decoration, and on some schemes it isn't marked at all.

FROM THE MARKER'S SIDE

The one that genuinely frustrates me is the six-figure trendline equation copied from a spreadsheet onto a graph of data measured to three figures. It's a small thing, and it tells me the numbers were never thought about.

13.3 One graph, fixed

The same data set, plotted twice.

BEFORE

A chart pasted from a spreadsheet. Grey background with horizontal gridlines. Title above it reading "Deflection vs Load". Axes labelled "Load" and "Deflection". Vertical axis running 0 to 4 when the data span 0.8 to 3.2. Points joined by straight segments. A legend reading "Series 1". A trendline with the equation $y = 0.40234x + 0.01187$ printed beside it. No caption, no figure number.

Score against the seven-point check: axis labels fail (no units), scale fails (data occupy 60% of the range), line fails (dot-to-dot), error bars fail, caption fails. Two of seven.

AFTER

White background, no gridlines, no chart title. Horizontal axis labelled "F / N" running 0 to 8; vertical axis "δ / mm" running 0 to 3.5. Seven crosses, with vertical error bars. One excluded point shown as an open circle. A single straight best-fit line through the seven retained points, extended to the axes. No legend, because there's one series.

Figure 3: End deflection against applied load for the mild steel cantilever ($L = 300\,\mathrm{mm}$). The line is a least-squares fit to the seven filled points, gradient $0.402 \pm$

0.008 mm N^{-1}. The open circle at 13.7 N was excluded (see Section 4.2). Horizontal error bars are smaller than the markers.

Seven of seven, and every change took under a minute. Note that the excluded point is still shown, with a different symbol and an explanation in the caption. Hiding it would be worse in every way.

13.4 Fitting, and what to say about it

If you fit by hand, draw the line, draw the triangle, and quote the gradient with its units.

If you fit numerically, say how: "a least-squares fit gave $m = 0.402 \pm 0.008\,\mathrm{mm\,N^{-1}}$". The uncertainty from the fit is marked, and quoting a gradient with no uncertainty is the same failure as quoting a result with no uncertainty.

For the uncertainty by hand: draw the steepest and shallowest lines that still pass through the error bars, take their gradients, and halve the difference. It's crude, it's accepted at undergraduate level, and it's far better than nothing.

> *A gradient is a measured quantity. It gets a value, an uncertainty, and a unit, exactly like every other number in the report.*

13.5 Software, briefly

Whatever you use, three settings matter more than the tool.

Turn off the defaults. No background fill, no gridlines unless they help reading, no chart title, no legend for a single series.

Markers, not just a line. The reader needs to see where the data actually is.

Export as vector, not a screenshot. PDF or SVG stays sharp; a pasted bitmap goes fuzzy at print size and looks careless.

Beyond that, spreadsheets, Python, MATLAB and hand-drawn graph paper all score identically if the seven points are satisfied. Nobody gets marks for the tool.

13.6 When a graph isn't the right answer

Two cases where students plot and shouldn't.

Three data points. A graph of three points is a table with extra steps. Present them as a table and quote the calculation.

Categorical comparisons. Four materials and their measured strengths isn't a line graph; it's a table, or a bar chart if the visual comparison genuinely helps.

BEFORE YOU SUBMIT

Take every graph from your last two reports and score each one out of seven. Most students score three or four, and always lose the same points: axis units, error bars, and the caption. Fix those three habits and the figures row on your rubric stops being a leak.

14

Captions That Stand Alone

A caption is the only part of a figure that gets read by somebody skimming, and it's usually four words long.

Fix that and you've fixed the cheapest recurring loss in the whole document.

14.1 The standard

> *A reader should understand a figure from its caption alone, without reading the body text. If they can't, the caption isn't finished.*

That's the whole rule. Everything below follows from it.

Weak	**Standing alone**
Figure 3: Graph of results	Figure 3: End deflection against applied load for the mild steel cantilever ($L = 300$ mm). The line is a least-squares fit, gradient 0.402 ± 0.008 mm N^{-1}. Error bars are smaller than the markers.
Figure 1: Apparatus	Figure 1: Cantilever arrangement. The beam is clamped at A; loads are applied at B, 300 mm from the clamp face, and deflection is read at C.
Table 1: Data	Table 1: Measured period against pendulum length. Each period is the mean of 20 oscillations, timed three times.

Notice the pattern in all three: *what it shows*, then *the conditions*, then *anything the reader needs to interpret it*.

14.2 The four ingredients

Item 4 is where the marks hide. Every visual decision a reader might question gets one clause: the excluded point, the suppressed zero, the log axis, the different symbol for the second data set.

14.3 Where captions go, and how they're numbered

Figures: caption below. Tables: caption above. Nearly universal, and getting it backwards is a small but visible tell.

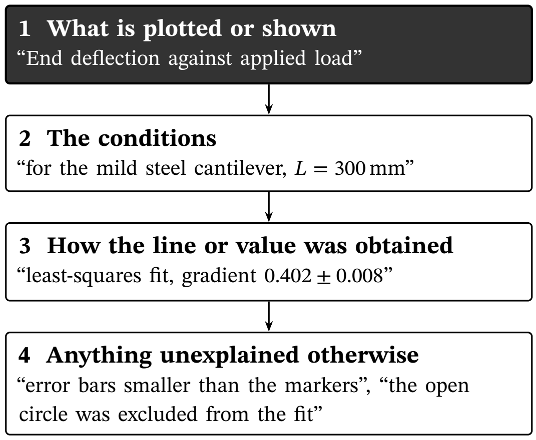

Figure 14.1: What goes in a caption. The first is compulsory; the others are the ones that make it stand alone.

Number sequentially, in order of first mention. Figure 1 is the first one referred to in the text, not the first one you drew.

Refer by number, never by position. “As shown in Figure 3”, not “in the graph below”. Layout moves; numbers don’t.

Every figure gets referred to. A figure that appears in the document and nowhere in the prose is unanchored, and on many schemes it isn’t marked.

14.4 The sentence that introduces a figure

Related to captions, and equally mishandled. When you refer to a figure in the text, say what the reader should notice.

Weak	Better
Figure 3 shows a graph of the results.	Figure 3 shows that deflection is proportional to load over the full range tested.
The results are shown in Figure 2.	The data in Figure 2 fall on a straight line through the origin, as the theory predicts.
See Table 1.	The measured periods in Table 1 vary by less than 0.4% across the amplitude range.

The pattern: the reference sentence states the *finding*, and the figure supplies the evidence. A reference sentence that only says “look over there” has wasted itself.

FROM THE MARKER’S SIDE

When every figure reference in a report is “Figure *n* shows the results”, I know before I reach the discussion that the analysis is going to be thin, because the student hasn’t yet said anything about their own data.

14.5 Ten captions, fixed

As written	As it should read
Graph 1	Figure 1: Extension against applied load for the 0.50 m steel wire.
The results	Figure 2: Measured period against pendulum length. Error bars show the standard error of five repeats.
Circuit	Figure 3: Potential divider used to set the bias point. Component values are nominal; tolerances are in Table 1.
Apparatus	Figure 4: Searle's bar arrangement. Thermocouples at A–D are spaced 50 mm apart along the lagged bar.
Table of results	Table 2: Measured yield and tensile strength for three 6082-T6 specimens, tested to BS EN ISO 6892-1.
Stress against strain	Figure 5: Engineering stress against strain for specimen 2. The 0.2% proof stress is marked.
Screenshot	Figure 6: Simulated temperature field at $t = 120\,\mathrm{s}$, 67 200-element mesh.
Bar chart	Figure 7: Measured stiffness for four materials. Bars show the mean of three specimens; whiskers show the range.
Photo of the rig	Figure 8: Test rig. The specimen is clamped at A and loaded at B; the LVDT at C measures deflection.
Data	Table 3: Parameters used in the analysis, with sources.

Every one is about ten seconds of work, and across a report that's two or three marks that require no thought about the subject at all.

14.6 Captions in long documents

Two extras once a document has a list of figures, which means anything from a design report upwards.

Keep the first sentence short, because in most systems the whole caption or its first clause goes into the list of figures. A caption whose first sentence runs four lines makes an unreadable list.

Make captions self-identifying across chapters. In a thesis, "Figure 4.3: Deflection against load" is better than "Figure 4.3: Results", because the reader browsing the figure list should be able to find the one they half remember.

BEFORE YOU SUBMIT

Take every figure and table from your last report. Cover the body text and read only the captions. Can you tell what each one shows, under what conditions, and how any line was obtained? Rewrite the ones that fail. It takes ten minutes for a whole report and it's marked on every rubric in both subjects.

Part IV

Derivations and Computation

15

Writing a Derivation Somebody Can Follow

A derivation in a report isn't a proof and it isn't lecture notes. It's an argument that a reader has to be able to check, at speed, without doing the algebra themselves.

That target changes what you write down.

15.1 Show the structural steps, skip the mechanical ones

The rule that governs everything else here.

> *Write the line where the method changes. Skip the lines where it only computes. A reader can expand a bracket; they can't guess which substitution you made.*

Structural steps are the ones where a decision happened: the substitution, the boundary condition applied, the approximation made, the theorem invoked. Mechanical steps are the algebra that follows automatically.

BEFORE

$$\delta = \frac{FL^3}{3EI} \quad \Rightarrow \quad E = \frac{FL^3}{3I\delta} = \frac{FL^3 \cdot 12}{3bd^3\delta} = \frac{4FL^3}{bd^3\delta} = 197 \text{ GPa}$$

Four equalities on one line, with the substitution $I = bd^3/12$ happening invisibly between the second and third, and the numbers appearing from nowhere.

AFTER

Rearranging for E:

$$E = \frac{FL^3}{3I\delta}.$$

For a rectangular section, $I = bd^3/12$, so

$$E = \frac{4FL^3}{bd^3\,\delta}.$$

Substituting $F = 7.85\,\text{N}$, $L = 0.300\,\text{m}$, $b = 25.0\,\text{mm}$, $d = 6.00\,\text{mm}$ and $\delta = 3.21\,\text{mm}$ gives $E = 197\,\text{GPa}$.

Same three steps. Each one is now checkable, and the substitution that was hiding in the middle has its own line.

15.2 One idea per line

Chained equalities are the commonest readability failure in student derivations, and the fix is mechanical: break the chain wherever the reason changes.

Chained	**Broken, with reasons**
$v^2 = u^2 + 2as =$ $0 + 2(9.81)(1.2) = 23.5$, so $v = 4.85$	$v^2 = u^2 + 2as$ With $u = 0$: $v^2 = 2as$ $= 2(9.81)(1.2) = 23.5\,\mathrm{m^2\,s^{-2}}$ $v = 4.85\,\mathrm{m\,s^{-1}}$

The right-hand version is longer on the page and much faster to read, which is the trade you want in a document somebody has to check.

15.3 Say why, in words, between the equations

Equations don't explain themselves. The connective sentences are what make a derivation followable, and they're usually four or five words.

Move	**The words**
Substitution	"Substituting $I = bd^3/12$,"
Boundary condition	"Applying $\delta = 0$ at $x = 0$,"
Approximation	"For small θ, $\sin\theta \approx \theta$, so"
Rearrangement	"Rearranging for E,"
Assumption used	"Assuming the beam remains elastic,"
Result quoted	"From the standard result for a cantilever [1],"

A derivation with no words between the equations is a wall. A derivation where every step has a four-word reason reads in half the time and shows the marker you know why each move is legal, which is what's being assessed.

15.4 Number the equations you refer to

Not all of them. The ones you come back to.

$$\delta = \frac{FL^3}{3EI} \tag{15.1}$$

…and later: "substituting the measured gradient into Equation (15.1) gives…"

Numbering everything clutters the page; numbering nothing forces you to write "the equation above", which breaks as soon as a page break moves it.

15.5 Approximations get stated and justified

Whenever you drop a term, say so and say why it's small.

BEFORE

For small angles this becomes $T = 2\pi\sqrt{L/g}$.

AFTER

For small amplitudes, $\sin\theta \approx \theta$ to within 0.5% for $\theta < 10°$, giving $T = 2\pi\sqrt{L/g}$. All measurements were taken below 8°, so this approximation holds throughout.

The second version does three things the first doesn't: it quantifies the error introduced, it states the range of validity, and it confirms the experiment stayed inside it. Each is marked, and the third is the one that connects the derivation to your actual data.

FROM THE MARKER'S SIDE

An approximation stated with its range of validity is one of the clearest signals that a student understands what they're doing. It's also, in industry, the difference between a calculation somebody can sign off and one they can't.

15.6 How much to include

Chapter 5 settled the principle: derive what's specific, cite what's standard. Two practical corollaries.

Long standard derivations go in an appendix, if they go anywhere. Reference them from the theory section and keep the body readable.

Numerical work goes in a sample calculation, once, not for every data point. One worked example of each distinct calculation, with real numbers, as in Chapter 7.

BEFORE YOU SUBMIT

Take a derivation from your last report and rewrite it with one idea per line and a four-word reason between every pair of equations. Then give it to a coursemate who didn't do that experiment and ask them to find the substitution. If they can't in ten seconds, break the chain further.

16

Symbols, Nomenclature, and Notation

Every symbol in your document means exactly one thing, is defined once, and is used consistently thereafter.

That sounds obvious. It's violated in most student reports, usually because the report was written in three sittings and L meant something different in each.

16.1 Define on first use, in the text

The definition belongs where the symbol first appears, in the sentence that introduces it, with its unit.

AFTER

…where δ is the end deflection (m), F the applied load (N), L the free length of the beam (m), E Young's modulus (Pa), and I the second moment of area (m^4).

Not in a glossary at the back, and not nowhere at all. A reader meeting I for the first time should not have to guess between second moment of area, current, and intensity.

16.2 When you also need a nomenclature table

Document	Nomenclature table?
Two-page lab report	No. Definitions in the text are enough.
Full lab report	Only if more than about ten symbols.
Design report	Usually yes.
Final-year project	Yes, always, in the front matter.
Anything with two symbol systems (e.g. mechanical and electrical)	Yes, grouped by system.

The table supplements the in-text definitions; it doesn't replace them. A reader on page 40 shouldn't have to flip to the front, and a reader starting at page 40 should be able to.

AFTER

Nomenclature

Symbol	Quantity	Unit
b	beam width	m
d	beam depth	m
E	Young's modulus	Pa
F	applied load	N
I	second moment of area	m^4
L	free length	m
δ	end deflection	m
σ	bending stress	Pa

Roman symbols first, then Greek, each alphabetically. Subscripts listed separately if there are many.

16.3 Collisions, and how to resolve them

Physics and engineering both reuse letters heavily, and within one document a collision is a real problem.

I	current, second moment of area, intensity, impulse
T	temperature, period, tension, torque
P	power, pressure, load, probability
ρ	density, resistivity, radius of curvature
σ	stress, conductivity, standard deviation, Stefan–Boltzmann
k	spring constant, thermal conductivity, Boltzmann constant, a generic constant

Three ways out, in order of preference:

Use the conventional symbol for the dominant quantity and rename the other. If your report is about beams, I is the second moment of area and current becomes i if it appears at all.

Subscript to disambiguate. T_{room} and T_{osc}. Remember from Chapter 11 that word-like subscripts are upright.

Say so explicitly. "Note that σ denotes stress throughout; the standard deviation is written s." One sentence, removes all doubt.

What you must not do is let a symbol mean two things in one document, even in different sections. It's the sort of thing that reads as carelessness and, in a long document, genuinely confuses the reader.

FROM THE MARKER'S SIDE

In a final-year thesis I once followed a symbol through two chapters before realising it had changed meaning at a chapter boundary. That's a few minutes of a reader's life, and it costs more goodwill than any single mistake in the analysis.

16.4 Vectors, matrices, and the small conventions

Thing	Style	Example
Scalar	italic	F
Vector	bold italic, or arrow	$\mathbf{F}$ or $\vec{F}$
Matrix	bold upright capital	$\mathbf{A}$
Unit vector	bold with hat	$\hat{\mathbf{n}}$
Magnitude of a vector	italic, no bold	$F = \lvert\mathbf{F}\rvert$
Average	bar or angle brackets	$\bar{x}$ or $\langle x \rangle$
Estimated value	hat	$\hat{E}$

Pick one vector convention and keep it. Mixing $\mathbf{F}$ and $\vec{F}$ in one document is the single most common notation inconsistency in engineering reports.

16.5 Units in the nomenclature, always

Every row of a nomenclature table carries a unit, and dimensionless quantities say so explicitly:

ε	strain	—
ν	Poisson's ratio	—
Re	Reynolds number	—

A dash or the word "dimensionless" is a deliberate statement. A blank cell reads as an omission, and on a rubric row about presentation it's scored as one.

BEFORE YOU SUBMIT

Take your longest report and list every symbol it uses, in order of first appearance. Check three things: each is defined on first use with a unit, none is used for two quantities, and the vector convention never changes. For most students the third one is where it breaks.

17

Computational Work: Code, Simulation, and Reproducibility

A growing share of physics and engineering coursework has no bench in it at all. You write code, run a simulation, and report what came out.

The replicator test from Chapter 1 applies unchanged, and it's harder to pass than students expect, because code has more hidden state than an optical bench.

17.1 The method section, for a simulation

Everything a bench method needs, with different nouns.

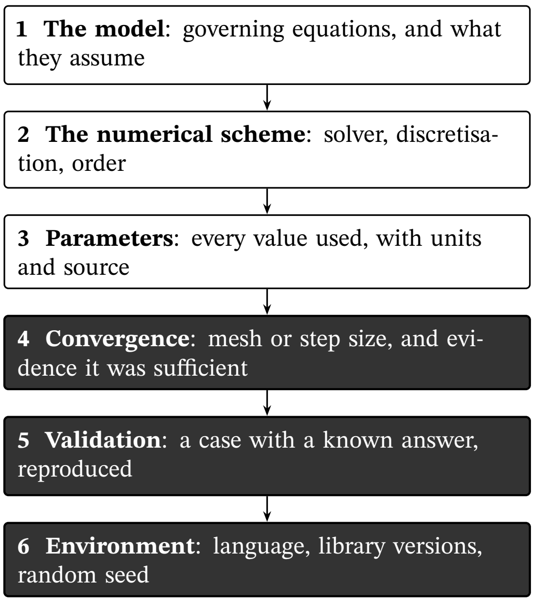

Figure 17.1: A computational method section. Items 4 to 6 are the ones students omit, and they are exactly the ones that make the work repeatable.

17.2 Convergence is the uncertainty section

In a simulation, the analogue of measurement uncertainty is numerical error, and the analogue of the contributions table is a convergence study.

AFTER

Table 4: Mesh convergence for the peak stress at the fillet.

Elements	**DOF**	σ_{max} / MPa	**Change**
4 200	13 100	128.4	—
16 800	51 600	139.7	8.8%
67 200	204 800	142.1	1.7%
268 800	816 300	142.6	0.35%

The solution changes by 0.35% between the two finest meshes, so the 67 200-element mesh was used for all subsequent runs, with an estimated discretisation error below 1%.

That table plus that sentence is the computational equivalent of quoting an uncertainty, and a report without it has reported a number with no indication of how much of it is real.

> *A simulation result with no convergence study is a number with no uncertainty. Refine until the answer stops changing, report the sequence, and state the residual error.*

17.3 Validate against something you know

Before trusting a model on the case you care about, run it on a case with a known answer.

- An analytical solution for a simplified geometry.
- A published benchmark case.
- A limiting case where the answer is obvious (zero load, infinite stiffness, steady state).
- Your own bench measurement, if you have one.

Then report the comparison with a number: "the model reproduces the analytical tip deflection for a uniform cantilever to within 0.4%".

A validation sentence like that does more for a marker's confidence than any amount of description of the software.

17.4 Reporting code

Three levels, depending on what the brief asks.

Level	**What to include**
Mentioned	Language, key libraries with versions, what the code does in two sentences
Extracted	The above, plus the core function or the governing loop in an appendix, commented
Submitted	The above, plus the full repository or archive, with a README saying how to run it

Whichever level, three things always go in the body:

The algorithm, in words or pseudocode. A reader shouldn't have to read your Python to know what the method was.

The parameters, in a table. Every constant, with units and where it came from.

The environment. "Python 3.12, NumPy 2.1, SciPy 1.14, seed 42". Results move between versions, and a seed makes a stochastic run reproducible.

FROM THE MARKER'S SIDE

The most common gap in computational reports is the random seed. A Monte Carlo result quoted to three significant figures from an unseeded run isn't reproducible even by the person who ran it, and that undermines every number in the section.

17.5 Figures from code

Two habits that prevent the failure mode from Chapter 20, where a figure and a table disagree because one was regenerated.

Generate every figure from a script, and keep the script with the report. When the data change, rerun.

Never re-touch a generated figure by hand. If the axis label is wrong, fix it in the script. A manually edited figure is one that cannot be regenerated, which means the next version will silently differ.

Otherwise, the seven-point check from Chapter 13 applies exactly as it does to hand-plotted data. Turn off the defaults, label the axes with units, export as vector.

17.6 Pseudocode, when it helps

For anything algorithmically non-obvious, pseudocode in the body beats code in an appendix, because it shows the method rather than the implementation.

Algorithm 1: adaptive step control

1. Take one step of size h; record y_1.
2. Take two steps of size $h/2$; record y_2.
3. Estimate the local error as $|y_2 - y_1|$.
4. If the error exceeds the tolerance, halve h and repeat from 1.
5. If it is below one tenth of the tolerance, double h for the next step.
6. Accept y_2 and advance.

Six lines, language-independent, and a reader can implement it in whatever they like. That's what the replicator needs, and it's what the marker is assessing.

17.7 What doesn't belong

Screenshots of code. Unreadable at print size, uncopyable, and they signal that the code wasn't in a form worth including.

Pages of listing in the body. Appendix, if anywhere.

A description of the software's user interface. Nobody needs to know which menu you clicked.

Default solver output dumped verbatim. Extract the numbers you need into a table.

BEFORE YOU SUBMIT

Take your last computational piece of work and write the six-item method section for it. Most students discover they cannot state the library versions or the seed, which means the work isn't reproducible even by them. Record those now, while you still can.

Part V

The Big Documents

18

Design Reports and Specifications

A lab report says what happened. A design report says what should be built, and why that option rather than the others.

That's a different document with a different structure, and students arriving from two years of lab reports usually write the wrong one.

18.1 The structure

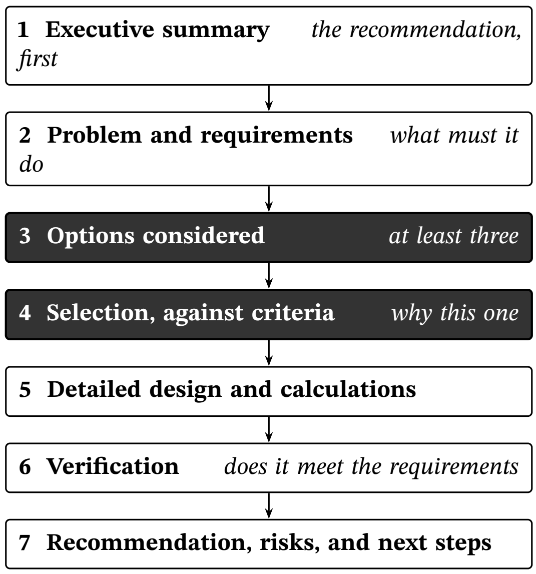

Figure 18.1: The design report. The two dark sections are what make it a design report rather than a long lab report, and they are the ones students under-write.

Sections 3 and 4 are the design report. A document that goes straight from the problem to one solution isn't a design report, it's a calculation, and it loses the marks for engineering judgement.

18.2 Requirements: the discipline of "shall"

Requirements are written as testable statements, and each one gets a number so the verification section can refer to it.

Not a requirement	A requirement
The bracket should be strong	R1. The bracket shall support a static load of 4.0 kN with a safety factor of at least 2.0
It must be lightweight	R2. The assembly mass shall not exceed 1.5 kg
It should be cheap	R3. Unit cost shall not exceed £25 at a batch size of 500
It needs to last	R4. Design life shall be 10 years under 10 000 load cycles per year

Three tests for a requirement: is it testable, is it quantified, and can you say afterwards whether it was met?

The convention is that *shall* marks a binding requirement and *should* a preference. Using them precisely costs nothing and reads as professional.

> *Number your requirements, then verify against the numbers. A verification section that says "R1: met, safety factor 2.4, see Section 5.2" is worth several paragraphs of prose about how strong the bracket is.*

18.3 Options, and the selection matrix

At least three options, evaluated against the same criteria. The criteria come from the requirements, weighted if the brief allows.

AFTER

Table 3: Concept selection against weighted criteria. Scores are 1 (poor) to 5 (excellent).

Criterion	Wt	A	B	C
Load capacity	0.35	5	4	3
Mass	0.25	2	4	5
Unit cost	0.20	4	3	2
Manu-facturability	0.20	5	3	2
Weighted total		**4.05**	**3.60**	**3.15**

Two things students get wrong here.

The weights need justifying. One sentence: "load capacity is weighted highest because R1 is the binding safety requirement."

The matrix informs the decision, it doesn't make it. If you override the highest score for a good reason, say so and give the reason. An engineer who follows a spreadsheet off a cliff is not demonstrating judgement, and the marks in section 4 are for judgement.

FROM THE MARKER'S SIDE

The weakest design reports have three options where two are obviously straw men, invented so the preferred one wins. It's visible immediately, and it costs more than presenting two serious options honestly.

18.4 Calculations in a design document

Different conventions from a lab report:

Every calculation states its load case and its assumptions. Worst-case loading, material properties with their source, safety factors with their justification.

Reference the standard. If a factor comes from a code or a standard, cite it by number. "A safety factor of 2.0 is applied in accordance with [4]" is a different statement from "a safety factor of 2.0 was chosen".

Show the check, not just the design. Calculating that a 6 mm plate is adequate is half of it; showing that it's adequate *under the worst case* is the other.

Sample calculations in the body, repetitive ones in an appendix.

18.5 Verification, by number

The section that closes the loop, and the one most student design reports skip or fudge.

Every requirement gets a row. Met or not met, with the evidence and where it lives.

AFTER

Table 7: Verification against requirements.

Ref	Requirement	Result	Evidence
R1	4.0 kN with SF ≥ 2.0	SF 2.4	ğ5.2, FEA
R2	Mass ≤ 1.5 kg	1.28 kg	ğ5.4, CAD
R3	Unit cost $\leq$ £25	£22.40	ğ5.6, quote
R4	10^5 cycles	Not verified	test proposed, ğ7.2

Four rows, and the fourth is the important one. "Not verified" with a proposed test is an honest, markable answer. Quietly omitting R4 is the failure, and it's the commonest one.

> *Every requirement gets a verdict, including the ones you couldn't verify. A verification table with a gap in it reads as an oversight; one that says "not verified, test proposed" reads as engineering.*

18.6 Specifications

A specification is a different document again: it says what the thing must do, with no design content at all.

The discipline is severe and worth learning. A specification that constrains the solution has failed at its job, because it removes options the designer might have used.

Over-specified	Correct
The housing shall be machined from 6082-T6 aluminium	The housing shall weigh no more than 400 g and withstand 2.5 kN
Four M6 bolts shall secure the plate	The joint shall carry 8 kN in shear and be removable without special tools
The controller shall use a PID loop	The controller shall settle within 2 s with less than 5% overshoot

The rule: specify the *what*, never the *how*, unless a specific solution is genuinely mandated by an interface or a standard, in which case say which.

BEFORE YOU SUBMIT

Take a design brief you've been set and write the requirements section alone: numbered, quantified, testable, using shall and should precisely. Ten requirements, half a page. Then check each against the three tests. In most student work, half of them turn out not to be testable, which is exactly the problem the verification section will run into later.

19

Technical Memos and Executive Summaries

Two short documents that carry disproportionate weight, in coursework and afterwards.

Both are written for somebody who will not read the long version. That single fact determines everything about them, and it inverts the structure students are used to.

19.1 The inversion

An academic report builds to its conclusion. A memo starts with it.

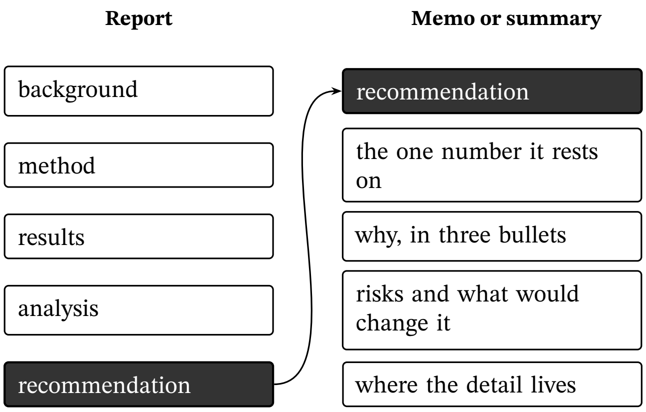

Figure 19.1: Report order versus memo order. The memo puts the answer first because the reader may stop after the first paragraph.

That arrow is the whole chapter. The thing your report spends eight pages earning is the thing your memo opens with.

19.2 A memo, complete

AFTER

To: R. Patel, Production
From: G. Tiwari, Test
Date: 14 March 2026
Subject: Bracket failures on line 3 — recommend switching to 6082-T6

Recommendation. Switch the line 3 bracket to 6082-T6 aluminium. This resolves the fatigue failures at a unit cost increase of £6 and no change to the fixing pattern.

Why. Three of the eleven returned brackets show fatigue cracking initiating at the fillet radius. Measured peak stress there is 142 MPa against a fatigue limit of 95 MPa for the current material at 10^7 cycles. 6082-T6 raises that limit to 130 MPa, and increasing the fillet radius from 2 mm to 4 mm reduces peak stress to 108 MPa. Both changes together give a margin of 20%.

Risks. The fillet change requires a new tool (£3 200, six weeks). If the line cannot wait, the material change alone gives a margin of 8%, which is positive but thin.

Detail. Full analysis, test data and drawings in report TR-2026-04, sections 4 and 6.

About two hundred words. A production manager can act on it without opening the report, and the person who wants the analysis knows exactly where to go.

19.3 The four rules

Subject lines carry the message. "Bracket failures on line 3 — recommend switching to 6082-T6" beats "Bracket investigation". Many readers decide whether to read on from the subject alone.

One page. If it doesn't fit, it's a report with a memo attached, which is fine, but the memo is still one page.

Numbers, not adjectives. "A margin of 20%" rather than "a significant improvement". The whole point of a technical memo is that the judgement is traceable to quantities.

Name the risk. A recommendation with no stated risk reads as naive, and the risk paragraph is where experienced readers look first.

> *Write the recommendation first, in the subject line and the first sentence. Everything after it is support, and a reader who stops at the end of paragraph one should still have the answer.*

19.4 The executive summary

Same logic, attached to a longer document, and a different thing from an abstract.

	Abstract	**Executive summary**
Reader	will read the report	won't
Purpose	help them decide to read	let them act without reading
Contains	what, how, result	recommendation, cost, risk
Length	4 sentences	up to a page
Technical level	full	minimal jargon
Numbers	the result	the decision-relevant ones

Using one where the other was wanted is a real and common loss. A design report brief that says "executive summary" and gets an abstract has missed the section's purpose entirely.

FROM THE MARKER'S SIDE

In industry the executive summary is often the only part read by the person who signs. Students find that idea uncomfortable, as though it devalues the work. It doesn't: it means the summary has to be exactly right, which is harder than writing the report.

19.5 Progress reports and update memos

The third short document you'll be asked for, usually on a project module.

Four headings, half a page: *done since last time*, *planned before next time*, *problems and what you need*, *schedule status against plan*.

The third heading is the one students soften. A progress report that never mentions a problem is not reassuring to a supervisor; it's uninformative, and the first real problem then arrives as a surprise. Say what's blocked and what you need, plainly, early.

19.6 Tone

Direct, impersonal about the work, and specific about actions.

Avoid three habits that creep in from essay writing: hedging every claim ("it could perhaps be suggested that"), inflating vocabulary ("utilise", "endeavour"), and apologising for the analysis. If the data are thin, say what would make them adequate and what it would cost.

BEFORE YOU SUBMIT

Take the last full report you wrote and reduce it to a one-page memo: subject line carrying the recommendation, the recommendation in a sentence, three bullets of evidence with numbers, one risk, and a pointer to the detail. If you can't name a recommendation, that's worth knowing about the report.

20

The Final-Year Project Report

The biggest document of your degree, usually worth a whole module, and almost always written in the last three weeks by people who intended to start earlier.

Most of this book applies unchanged. This chapter is what's different at eighty pages.

20.1 The structure, and where it differs

Section	What's different from a lab report
Abstract	Still four sentences. Still written last.
Introduction	Now substantial: context, motivation, aims, and an explicit outline of the report
Literature review	New. What's known, what isn't, and where your work sits
Method	Now several chapters, one per strand of work
Results	Often interleaved with analysis, chapter by chapter
Discussion	Draws the strands together; the highest-value chapter
Conclusions	Answers the aims one by one
Further work	Its own section, specific and actionable

Two of those are new and both are marked heavily.

The literature review isn't a summary of everything you read. It's an argument that ends in your aims: here's what's known, here's the gap, therefore this project. If it doesn't end by justifying your aims, it's a reading list.

Further work is not "more data could be collected". It's specific: what you'd do next, why, and what it would resolve. Three or four concrete items beat a page of vagueness.

20.2 Aims, numbered, and answered

Number the aims in the introduction and answer them by number in the conclusions.

AFTER

Introduction, ğ1.3. The aims of this project were:

A1. To characterise the fatigue behaviour of the current bracket under representative loading.

A2. To identify the dominant failure mechanism.

> A3. To propose and evaluate a design change that raises the fatigue margin above 15%.
>
> **Conclusions, ğ7.1.** A1 was met: the current bracket survives 3.2×10^6 cycles at 142 MPa peak stress (ğ4.3). A2 was met: failure initiates at the fillet radius in all eleven specimens (ğ4.5). A3 was partially met: the proposed change raises the margin to 20% by analysis (ğ6.2), but the fatigue testing to confirm it was not completed within the project period.

That structure does two things. It makes the report self-auditing, and it lets you say "partially met" honestly, which reads far better than claiming success or quietly not mentioning it.

> *Number the aims and answer them by number. A conclusions section that doesn't map onto the aims is the single most common structural failure in final-year reports, and it's mechanical to prevent.*

20.3 Writing it in the wrong order, on purpose

Nobody writes a thesis front to back. The order that works:

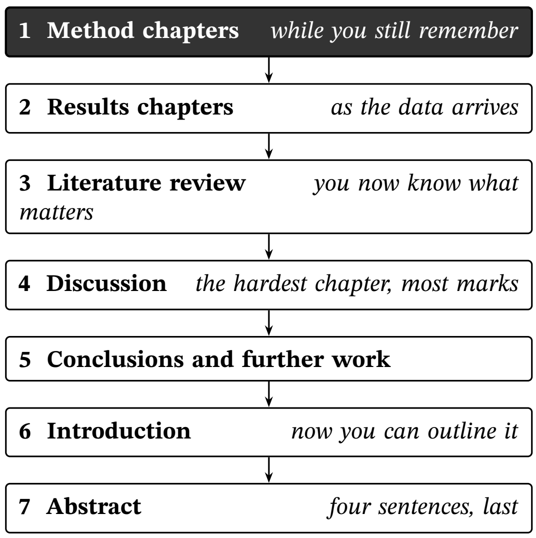

Figure 20.1: The order to write a project report in. The introduction and abstract come near the end, because you cannot introduce a document that does not exist yet.

Write the method chapters during the work, not after. Method is the easiest thing to write and the fastest thing to forget, and a student who writes it in week 6 has removed a week's work from the final scramble at no cost.

20.4 The literature review, as an argument

The chapter students find hardest, because they've been taught to summarise and the assessment wants an argument.

A summary reads: *Smith did X. Patel did Y. Chen did Z.* A review reads: *X and Y established that failure initiates at the fillet. Neither examined surface finish, which Z suggests may dominate at low stress amplitudes. This project therefore measures…*

Two rules fix most student reviews:

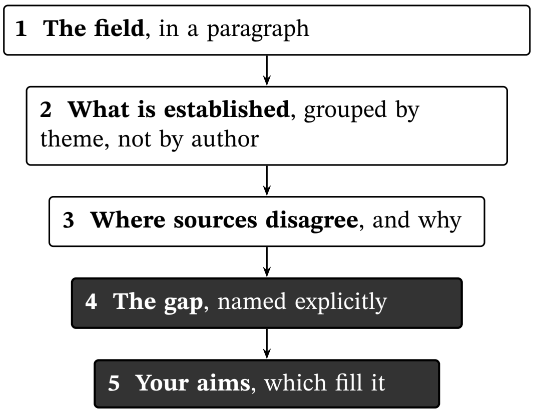

Figure 20.2: The literature review as a funnel. It has to end at your aims, or it is a reading list.

Group by theme, not by paper. A paragraph per source is a summary. A paragraph per idea, citing several sources, is a review.

Every paragraph points forward. If a paragraph could be deleted without weakening the case for your aims, delete it.

FROM THE MARKER'S SIDE

The tell for a summary-style review is that the paragraphs could be reordered without anything breaking. In a real review they can't, because each one sets up the next.

20.5 The thing that actually goes wrong

Not writing quality. Version control and figures.

By week ten you'll have four versions of chapter 4, three of them in your downloads folder, and figures generated by a script you've since changed.

Three habits, none of which take time:

One folder, dated filenames or a repository. If you know git, use it. If you don't, a folder per week is fine. What isn't fine is "report_final_v3_REAL_final.docx".

Figures generated by a script that lives with the report. When the data changes, rerun and the figures update. Manually re-pasted charts are how reports end up containing two different versions of the same graph.

A single bibliography file from day one. Add each reference the day you read it, with the DOI. Reconstructing forty references in the last week is a genuine misery and produces the referencing errors in Chapter 23.

FROM THE MARKER'S SIDE

The failure mode I see most in project reports isn't bad writing. It's a figure whose numbers don't match the table on the previous page, because one was regenerated and the other wasn't. It undermines everything around it, and it's entirely preventable.

20.6 Length, and the appendices

Whatever the limit is, the body should be under it and the appendices should carry the rest.

Into the appendices: full data sets, long derivations, code, drawings, calibration certificates, risk assessments, and anything the reader doesn't need in order to follow the argument.

Into the body: everything the argument needs. If a reader has to turn to an appendix to follow your reasoning, it belongs in the body.

Appendices are referenced from the body, numbered, and listed in the contents. An appendix nobody points to is a pile.

20.7 The last week

- **Seven days out:** all chapters drafted, however roughly.
- **Five days out:** full read-through for structure only. Are the aims answered? Does each chapter have a job?
- **Three days out:** figures, tables, captions, numbering, references. Chapter 22's checklist.
- **Two days out:** print it. Read it on paper. You will find things you cannot see on screen.
- **One day out:** submit. Do not spend the last day writing new material; spend it making sure the document is complete and correct.

That schedule assumes the writing started in week 6, which is the actual recommendation hiding inside this chapter.

BEFORE YOU SUBMIT

Today, whatever stage your project is at, write the method chapter for the work you've already done. It's the easiest chapter, you'll never remember the settings better than now, and it removes a week from the panic in April.

21

Writing With Other People

Group reports are marked as one document, and they usually read like four.

The problem isn't collaboration. It's that the standard student approach, splitting the sections and stapling them together, produces a document with four voices, three notations, two conflicting numbers, and nobody responsible for the whole.

21.1 Split by section, not by task

The first decision, and the one that determines how bad the merge will be.

Splitting that fails	Splitting that works
"You do results, I'll do discussion"	"You own the whole thermal strand: its method, results and analysis"
Four people write two pages each	Two people write, two people test and review
Everyone writes their own section in isolation	One person owns the document and its consistency

Splitting by *strand of work* rather than by *section* means each person writes a coherent argument, and the seams fall at natural boundaries instead of in the middle of the reasoning.

> *One person owns the document. Not the writing, the document: notation, structure, numbering, and the final read-through. Without that role the report will contradict itself somewhere, and the marker will find it.*

21.2 Agree the conventions before anybody writes

Fifteen minutes at the start, and it prevents most of the merge pain.

The internal deadline is the one that saves the report. Three days of merge, read-through and consistency work is the minimum for a document written by four people, and a group that plans to finish on the deadline will submit something that reads like four reports.

21.3 Making four voices into one

Even with a good split, the final document needs a pass that only one person does.

- **Notation sweep.** One symbol, one meaning, one style. This is where $\mathbf{F}$ and $\vec{F}$ get reconciled.
- **Tense and voice sweep.** Whatever was agreed, applied throughout.

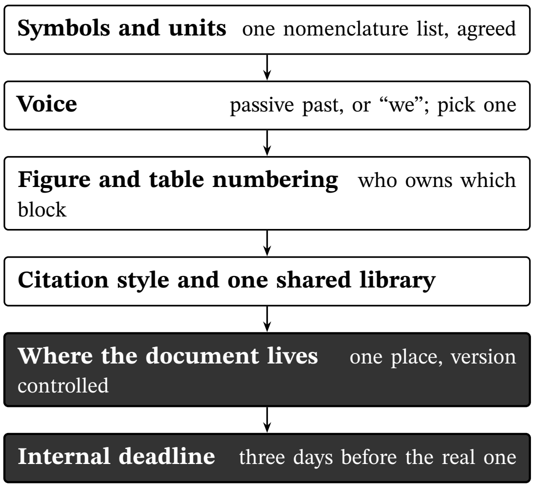

Figure 21.1: The pre-writing agreement. Fifteen minutes, and every item on it is something that otherwise gets discovered during the merge at 2am.

- **Number sweep.** The mass quoted in section 3 and the mass quoted in section 6 must agree. They very often don't.
- **Figure sweep.** Sequential numbering, consistent style, every one referenced.
- **Read-aloud pass on the joins.** The paragraph either side of each section boundary, read out loud. Seams are audible.

FROM THE MARKER'S SIDE

Contradictory numbers between sections is the commonest thing I flag in group reports, and it's the one that costs most, because it makes me doubt every other number in the document.

21.4 Peer contribution, and being honest about it

Many group modules ask for a contribution statement. Write it accurately.

Two failure modes, both damaging. Claiming equal contribution when it wasn't is unfair to whoever did the work and usually visible to the supervisor anyway. And under-claiming your own contribution out of politeness distorts the record for everybody.

If the split was uneven, say what each person did, factually, without editorialising. "A. wrote the thermal model and sections 4 and 5; B. ran the tests and produced Figures 6–11" is a contribution statement. "Everyone contributed equally" is usually a fiction and is read as one.

21.5 When somebody isn't delivering

It happens on most group projects, and the way students handle it makes things worse: they say nothing, absorb the work, and complain afterwards.

Three steps, in order:

Ask early and specifically. "Can you send me the draft of section 4 by Thursday?" beats waiting to see.

Escalate to the supervisor early, factually. Not to blame, but because supervisors can reallocate work when there's still time. In week ten there isn't.

Document what was agreed. A shared task list with dates and owners isn't bureaucracy; it's what makes the contribution statement writable and the escalation credible.

21.6 Version control, briefly

If your group knows git, use it, and commit early and often.

If it doesn't, use one cloud-hosted document with real collaborative editing, and never work on local copies. The failure mode this prevents is the one where two people edit chapter 4 in parallel and one version wins silently.

Whatever you use, agree it in the first meeting. A group that is still emailing files around in week 8 will lose work.

BEFORE YOU SUBMIT

At your next group project meeting, spend fifteen minutes agreeing the six items in Figure 20.1 and writing them down where everyone can see them. Then name the document owner. It's the highest-return quarter of an hour available to a student group, and almost nobody spends it.

Part VI

Finishing

22

Revision, Proofreading, and Submission

The last two hours of a report are worth more than any other two hours, and most students spend them writing new material.

They shouldn't. By that point the marks are in fixing what's there.

22.1 Three passes, in this order

Never try to do them at once. Each pass looks for one kind of problem, and mixing them means you fix commas while a section is in the wrong place.

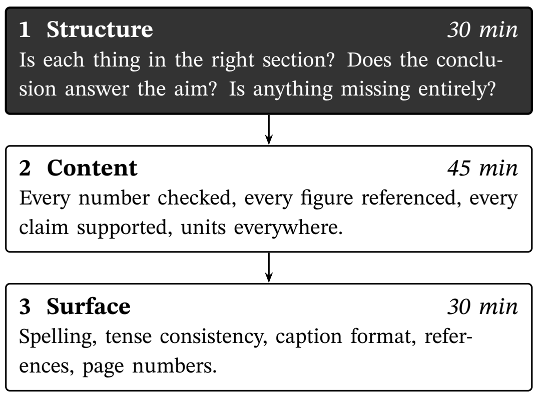

Figure 22.1: Three passes, biggest problems first. Doing them in the other order means polishing sentences you are about to delete.

22.2 Pass 1: structure

Read only the headings, the first sentence of each paragraph, and the figures. Twenty minutes for a report, an hour for a thesis.

Three questions:

Is each thing in its section? The commonest finding is analysis sitting in the results, per Chapter 7.

Does the conclusion answer the aim, in the same terms? Put them side by side, as in Chapter 10.

Is a rubric row missing? Go through the marking criteria and point at where each row is satisfied. If you can't point at it, the marker won't find it either.

That third check catches the expensive failures: no uncertainty discussion, no comparison with the accepted value, no assumptions stated.

22.3 Pass 2: content

Slower, and this is where errors that would embarrass you get caught.

- **Every number appears once, or agrees everywhere.** Check the abstract against the conclusion against the results. They disagree more often than you'd believe.
- **Every figure and table is referenced by number** in the text.
- **Every claim has support**: a number, a citation, or a figure.
- **Every value has a unit and a sensible precision.**
- **Every symbol is defined once** and never reused.
- **Sample calculations reproduce the tabulated values.** Actually redo one.

FROM THE MARKER'S SIDE

The abstract quoting one value and the conclusion another is something I see most weeks. It usually happens because the analysis was redone and the abstract wasn't. It reads worse than any grammatical error.

22.4 Pass 3: surface, and how to actually see it

You cannot proofread your own writing on the screen you wrote it on. Your eye supplies what you meant.

Four ways to break that, in order of effectiveness:

Print it. Errors on paper are visible in a way screen errors aren't. If you do one thing from this chapter, do this.

Read it aloud. Slowly. Your ear catches missing words, doubled words, and sentences that never end.

Change the appearance. Different font, different zoom, or export to PDF and read that. It's enough to defeat familiarity.

Read it backwards, by paragraph, for spelling only. It removes the meaning and leaves the letters, which is what you're checking.

And run a spellchecker, but don't trust it. It won't flag "the beam was clamed", "a form of the wave equation" where you meant "force", or any of the homophone errors that make a report look careless.

22.5 The submission checklist

Mechanical, and it catches the failures that have nothing to do with writing.

☐	File format as specified (PDF unless told otherwise)
☐	Filename as specified, including your ID if required
☐	Page limit met, including or excluding appendices as stated
☐	Name, ID, module code, date, title on the front
☐	Page numbers present
☐	All figures and tables numbered, captioned, referenced
☐	Reference list complete and in one style
☐	Appendices referenced from the body
☐	Data or code attached if required
☐	The PDF opens on a different machine and the figures render
☐	Submitted, and the receipt saved

That last-but-one row is not paranoia. A thesis whose figures were linked rather than embedded, opened on the marker's machine as empty boxes, is a real thing that happens every year.

22.6 Cutting, when you're over the limit

Almost every report needs cutting, and students cut the wrong things: they trim the discussion because it's last, and keep the method because it was hard to write.

Cut in this order.

1	Copied brief or restated aim. Pure duplication.
2	Explanations of standard technique. The replicator knows.
3	Derivation available in the course text. Cite it instead.
4	Narrative and hedging. "It was decided that we would then..."
5	Any paragraph that answers no question from Chapter 1.
6	Second and third figures showing the same thing.
7	Raw data in the body that belongs in an appendix.
Never cut: the uncertainty discussion, the comparison paragraph, the assumptions verdict, or units.	

Most reports lose 20% of their length to items 1–4 without losing a single mark, and usually gain some, because what remains is easier to search.

> *Cut duplication and narrative before you cut analysis. If you're still over after items 1–7, the report is over-scoped rather than over-written, and the fix is to move a strand into an appendix, not to compress the discussion.*

22.7 Time budget for the last day

For a four-page report: 30 minutes structure, 45 content, 30 surface, 15 checklist. Two hours, and it's worth more than a third page of new discussion.

For a project report: half a day, and the print-and-read pass is not optional.

> *Stop writing before you stop working. The last two hours belong to revision, and a report that gains a paragraph but loses the revision pass scores lower every time.*

BEFORE YOU SUBMIT

On your next report, finish the writing two hours before the deadline regardless of state, then run the three passes with a timer. Note how many errors pass 2 finds. For most students it's between six and fifteen, and several of them are numbers.

23

References, Data, and Honesty

The chapter nobody reads until something goes wrong.

Most of it is mechanical. The part that isn't is short, and it matters more than everything else in this book.

23.1 Referencing, mechanically

Two systems, and your department will specify one.

	Numeric (IEEE, Vancouver)	Author–date (Harvard, APA)
In text	"…as shown in [4]."	"…as shown by Patel (2019)."
Order	by first appearance	alphabetical
Common in	engineering, physics	some engineering, most science
Advantage	compact in dense text	the reader recognises the source

Whichever you use: one style, applied everywhere, including figure sources and data sets. Mixed styles in one document is a presentation mark lost for no reason.

Use a reference manager, and add each entry the day you read the source. Reconstructing a bibliography in the final week is where the errors come from: wrong years, missing page numbers, and the classic, a reference in the list that's cited nowhere.

23.2 What needs a citation

Cite it	**Don't bother**
A standard result you quote rather than derive	$F = ma$
A material property value	The definition of density
A method you followed from a paper or standard	Standard lab technique
A number you didn't measure	Your own measurements
A claim about what's known in the field	Common knowledge in the subject
A figure or data set you didn't produce	Your own figures

The test: could a reader reasonably ask "how do you know that?" If yes, and the answer isn't "I measured it", cite something.

Material properties deserve a specific note. "Young's modulus for mild steel is 200 GPa" needs a source, because the value varies with composition and the source is what makes your comparison meaningful. An uncited accepted value is a comparison against a number from nowhere.

23.3 Figures and data you didn't make

Any figure reproduced from another source carries its source in the caption, and in many cases needs permission for anything published. For coursework, the caption citation is the requirement:

> Figure 4: Fatigue curve for 6082-T6 aluminium. Reproduced from [7].

If you redrew it from somebody's data, say that instead: "plotted from data in [7]". The distinction matters and takes three words.

The same applies to data sets, code libraries, and anything generated by a tool that isn't yours. Say what you used and what version.

23.4 Where the real line is

Everything above is convention. This part isn't.

> *Report what you measured. If you didn't measure it, don't write it as though you did. There is no coursework mark worth crossing that line for, and in professional practice the consequences are of a completely different kind.*

The forms it takes in student work are usually small and rationalised at the time:

Adjusting a data point that spoils an otherwise good line.

Reporting the accepted value's neighbourhood when your measurement gave something else.

Inventing the reading you forgot to take, because the experiment is over and the lab is closed.

Copying a coursemate's data for the run you missed.

Each is understandable under deadline. Each is also, in every institution, academic misconduct, and each is more detectable than students think: fabricated data is usually too well behaved, and duplicated data sets are identical in ways real measurements never are.

23.5 What to do instead, in each case

There's always a legitimate move, and it usually scores better than the fabrication would have.

Situation	What to write
A point spoils the line	Report it, exclude it from the fit if justified, and say why in the discussion
Result disagrees with accepted	Say so with numbers and investigate mechanisms (Chapter 9)
Missing a reading	Report the data you have and say what's missing and why
Whole run failed	Report the failure, its likely cause, and what you'd do differently. This is a real result
Ran out of time	Say what was completed and what wasn't. Partial work honestly reported is markable

FROM THE MARKER'S SIDE

A report that says "the apparatus failed at 14:20 and only four of the eight loads were completed; the four are reported below" is a perfectly good report. It's marked on what's there, and it's a great deal better than eight suspiciously tidy points.

23.6 Collaboration: where the boundary sits

Group work has explicit rules and they vary by module, so read them. Where they're unwritten, three defaults are safe almost everywhere:

Shared data, individual analysis and writing is normal for lab partners. Say in the method that the data were taken jointly.

Discussing how to approach an analysis is fine. Writing sentences together for an individually assessed report isn't.

Anything you'd rather the marker didn't know about is the signal. If you're wondering whether to mention it, mention it.

23.7 Tools, and the current expectation

If you used software to analyse, cite it and give the version. If you used a tool to help write or check, follow your institution's declaration policy, which almost certainly exists now and which you should read rather than assume.

The underlying principle hasn't changed with the tools: the reader needs to know how the document was produced, so they can judge what it's worth. That's the same principle as the method section, applied to the writing itself.

BEFORE YOU SUBMIT

Find your department's academic integrity policy and its data-handling guidance, and read them once, this week, before you're under deadline pressure. Twenty minutes, and the point is that you'll know the answer at 2am on the night it matters, when nobody reads policies.

Part VII

Toolkit

A

Five Report Makeovers

Five real sections, rewritten. Same experiment, same student, same understanding. The only difference is the writing, and in each case the rewrite took under fifteen minutes.

A.1 Makeover 1: a method nobody could repeat

BEFORE

Method
The apparatus was set up as shown in the diagram. The beam was clamped at one end and we made sure it was secure. Masses were then added to the end of the beam and the deflection was measured using a gauge. We took several readings and calculated an average. The length of the beam was measured using a ruler.

What's wrong. Nothing here can be repeated. No dimensions, no tolerances, no instrument models, no resolutions, no load range, no increment, no number of repeats. "Made sure it was secure" is not a procedure, and "a ruler" is not an instrument specification.

AFTER

Method
A mild steel beam of rectangular section, 25.0 ± 0.1 mm wide and 6.00 ± 0.05 mm deep (measured with vernier callipers, resolution 0.02 mm), was clamped horizontally in a bench vice, leaving a free length of 300 ± 1 mm measured from the clamp face with a steel rule.

Point loads were applied at the free end using calibrated slotted masses in 200 g increments to a maximum of 2.00 kg. End deflection was measured with a dial gauge (Mitutoyo 2046S, resolution 0.01 mm) mounted on a magnetic base and zeroed at zero load.

Three readings were taken at each load, with the load fully removed and reapplied between readings, and the mean recorded. The apparatus is shown in Figure 1.

Three paragraphs, and it can be repeated tomorrow by a stranger. Note the tolerance on every dimension, the resolution of every instrument, and the detail that the load was removed between repeats, which is what makes them independent readings rather than three looks at the same number.

A.2 Makeover 2: results doing the discussion's job

BEFORE

Results
The results are shown in the table. As can be seen, the deflection increased with load, which is what we expected from the theory. The graph was a straight line showing that the relationship is linear, proving Hooke's law. The gradient was 0.402 which gives a value for E of about 197 GPa. This is quite close to the accepted value so the experiment worked well, although the point at 1.4 kg was a bit off, probably because of an error in the measurement.

What's wrong. It's a discussion section wearing a results heading, and a weak one. There's no table reference, no units on the gradient, no uncertainties, and "proving" is much too strong for four points and a line.

AFTER

Results
Measured end deflections are given in Table 2 and plotted against applied load in Figure 3.
A least-squares fit to the seven retained points gives a gradient of $0.402 \pm 0.008\ \mathrm{mm\ N^{-1}}$ and an intercept of 0.01 ± 0.03 mm.
From $E = 4FL^3/bd^3\delta$, equivalently $E = L^3/3Im$ with $I = (4.50 \pm 0.12) \times 10^{-10}\ \mathrm{m}^4$, this gives

$$E = 197 \pm 6 \text{ GPa}.$$

The reading at 1.4 kg lies 0.31 mm above the fitted line, more than seven times the residual standard deviation of the other points, and was excluded from the fit.

Everything interpretive has gone to the discussion. What remains is the record: what was measured, what was fitted, what came out, and which point was excluded, with the number that justifies the exclusion.

A.3 Makeover 3: the discussion that narrates

BEFORE

Discussion
The experiment was successful and produced a good value for Young's modulus. The graph showed a clear linear relationship as predicted by the theory. The value obtained was close to the accepted value, with only a small percentage error, which shows the method was accurate. There were some errors in the experiment, mainly human error in reading the gauge and possibly the beam not being perfectly clamped. These could be reduced by taking more readings and being more careful. Overall the experiment achieved its aim.

What's wrong. Everything and nothing. Every sentence is true and none of it is analysis. No number for the agreement, no reference to the uncertainty, no identification of what limited the result, and the two improvements suggested wouldn't have helped.

AFTER

Discussion
The measured value $E = 197 \pm 6$ GPa agrees with the accepted value of 200 GPa for mild steel [2]. The deviation of 1.5% is well inside the 3.4% combined uncertainty, so the data are consistent with the Euler–Bernoulli prediction over the load range tested.
The uncertainty is dominated by the beam depth. Because $\delta \propto 1/d^3$, the 0.8% uncertainty in d contributes 2.4% of the 3.4% total, against 2.0% from the gradient and 1.0% from the length. Measuring d with a micrometer (resolution 0.01 mm) would reduce its contribution to about 0.6% and the total to roughly 2.4%. Additional loading repeats would not help: the scatter about the line is already small, and the limiting terms are systematic.
The intercept, 0.01 ± 0.03 mm, is consistent with zero, as an ideal rigid clamp requires. A significantly positive intercept would have indicated clamp compliance, so its absence supports the rigid-clamp assumption of Section 2.
The excluded 1.4 kg point was taken immediately after the clamp was re-tightened. A shorter effective free length would reduce deflection at fixed load, which is the direction observed, so clamp movement is the likely cause rather than a gauge misreading.

Four paragraphs, four jobs: compare, attribute, test the assumptions, account for the anomaly. Note that the anomaly explanation checks the *direction* of the effect, which is what separates analysis from a list of things that might have gone wrong.

A.4 Makeover 4: uncertainty as arithmetic only

BEFORE

Uncertainty
The percentage uncertainties were combined as follows: $\Delta E/E = 3\Delta d/d + 3\Delta L/L + \Delta m/m + \Delta b/b = 3.4\%$. Therefore $\Delta E = 6.7$ GPa. So $E = 197.34 \pm 6.7$ GPa.

What's wrong. The arithmetic is right and it's about a third of the marks. There's no statement of which term dominates, no comment on whether it could be reduced, no verdict on agreement, and the final quotation breaks both rounding rules.

AFTER

Uncertainty
Contributions to the fractional uncertainty in E, from $E = 4FL^3/bd^3\delta$:

Quantity	**Rel. unc.**	**Contribution**
Depth d (as d^3)	0.8%	2.4%
Gradient m	2.0%	2.0%
Length L (as L^3)	0.33%	1.0%
Width b	0.4%	0.4%
Combined		**3.4%**

The depth measurement dominates, because d enters cubed: a 0.8% measurement uncertainty becomes a 2.4% contribution. Combining in quadrature gives 3.4%, so

$$E = 197 \pm 6 \text{ GPa}.$$

The accepted value of 200 GPa lies within one uncertainty of this result.

Same arithmetic. Now it says which term matters and why, it quotes the result to a precision that matches its uncertainty, and it delivers the verdict the discussion will build on.

A.5 Makeover 5: a conclusion that wanders

BEFORE

Conclusion
In conclusion, this experiment was carried out to find Young's modulus by clamping a beam and adding masses. The value found was 197.34 GPa which is quite close to the accepted value of 200 GPa. The experiment was reasonably successful. In future it would be interesting to test other materials such as aluminium and to investigate what happens beyond the elastic limit, which might show plastic deformation. There were also some errors which affected the accuracy.

What's wrong. Method detail that belongs in the method. Hedging ("quite close", "reasonably successful"). Two ideas that appear nowhere else in the report. A number quoted to five figures. And no clear answer to the aim.

AFTER

Conclusion
Young's modulus for the mild steel beam was determined as $E = 197 \pm 6$ GPa from the gradient of end deflection against applied load. This agrees with the accepted value of 200 GPa within experimental uncertainty, supporting the Euler–Bernoulli prediction over the load range tested.
The uncertainty is dominated by the measurement of beam depth; a micrometer would reduce the total uncertainty to approximately 2.4%.

Two sentences plus one. It answers the aim in the aim's own terms, quotes the result properly, and names the limiting factor. The aluminium idea, if it's worth keeping, belongs in a further-work section, having first been discussed.

A.6 What the five have in common

Look back at the five rewrites and notice how little of it is writing skill.

Every improvement came from a fixed move from this book: put the interpretation in the discussion, name the dominant uncertainty, round the value to match it, check each assumption against the data, check the direction of a proposed mechanism, answer the aim in its own terms.

None of it required understanding the beam any better. All of it is available to you in fifteen minutes per section, on the report you're writing this week.

B

Skeletons for Six Documents

Paste-ready structures. Each shows the sections, roughly what each should contain, and a proportion of the total length.

1. The short lab report (2 pages)

Section	Share	Contains
Title and aim	5%	What was measured, by what means; aim names a quantity
Theory	15%	The relationship, cited; assumptions; what will be plotted
Method	20%	Apparatus with models and resolutions; dimensions with tolerances; procedure; repeats
Results	25%	Table, graph, the fitted gradient, the extracted result with uncertainty
Discussion	25%	Compare, attribute, test assumptions, anomalies
Conclusion	10%	Answer the aim, with the number

2. The full lab report (6–10 pages)

As above, plus:

- **Abstract** (four sentences: what, how, result, meaning).
- **A separate uncertainty section**, with the contributions table.
- **Sample calculations**, one of each distinct type.
- **References.**
- **Appendices**: full data, long derivations, calibration records.

3. The design report

Section	Share	Contains
Executive summary	5%	The recommendation, first; cost; risk
Problem and requirements	15%	Numbered, quantified, testable; shall and should used precisely
Options considered	15%	At least three, seriously
Selection	15%	Weighted criteria, justified weights, the judgement
Detailed design	25%	Calculations with load cases, assumptions, standards cited
Verification	15%	Each requirement, by number, met or not
Recommendation and risks	10%	Next steps, and what would change the answer

4. The technical memo (1 page)

To / From / Date	
Subject	Carries the recommendation, not the topic
Recommendation	One or two sentences, first
Why	Three bullets, each with a number
Risks	What could go wrong, what it would cost
Detail	Where the full analysis lives

5. The final-year project report

Section	Share	Contains
Abstract	1%	Four sentences
Introduction	10%	Context, motivation, numbered aims, report outline
Literature review	15%	An argument ending in the gap your aims fill
Method chapters	20%	One per strand of work
Results chapters	25%	Data and analysis, chapter by chapter
Discussion	15%	Draws the strands together
Conclusions	8%	Answers each aim by number
Further work	4%	Three or four specific, actionable items
Appendices	—	Data, code, drawings, long derivations

6. The progress report (half a page)

Done since last time	Specific, with dates
Planned before next	Specific, with dates
Problems and needs	Say them plainly and early
Schedule status	Against the plan, in weeks ahead or behind

Which sections carry the marks

Across every document type in this appendix, three things are marked heavily and written last: the discussion or selection, the uncertainty or verification, and the figures. Budget your writing time against that rather than against section length.

C

The Uncertainty Phrasebook

Sentences that score, for the section where students most often produce arithmetic and no words.

Use them as shapes, not as strings to paste.

Quoting a result

Weak	Use
E was 197.34 GPa	$E = 197 \pm 6$ GPa
The error was 6.7	The combined standard uncertainty is 3.4%, giving ± 6 GPa
$E = 197 \pm 6.7$ GPa	$E = 197 \pm 6$ GPa (uncertainty to one significant figure)

Naming the dominant term

- "The uncertainty is dominated by the depth measurement, which contributes 2.4% of the 3.4% total."
- "Because $\delta \propto 1/d^3$, the 0.8% uncertainty in d enters as 2.4%."
- "The gradient and the depth contribute comparably; the width is negligible at 0.4%."

Saying whether it agrees

Weak	Use
It was quite close	The accepted value lies within one uncertainty of the measured value
There was a 1.5% error	The 1.5% deviation is smaller than the 3.4% uncertainty, so the values agree
The result was accurate	The measured and accepted values agree within experimental uncertainty
It was a bit off	The measured value lies 3.2 uncertainties below the accepted value; the two do not agree

When it doesn't agree

- "The measured value is 23% below the accepted value and more than seven uncertainties away; the two do not agree."
- "The scatter about the fit is small, so the discrepancy is systematic rather than random."
- "If the free length were 5 mm longer than measured, E would be underestimated by about 5%, which is the direction observed."
- "Re-measuring L from the clamp face would test this."

Note the third one: every proposed mechanism states the *direction* of its effect. A cause that would move the result the wrong way isn't an explanation.

Random versus systematic

- "The scatter about the line reflects random uncertainty in the gauge reading; repeating reduces it as $1/\sqrt{N}$."
- "A zero-offset in the gauge would shift every point equally and would not appear as scatter."
- "Repeats would not reduce this term, because it is systematic."

Improvements that score

Useless	**Marked**
Take more readings	Repeats would not help; the dominant term is systematic
Use better equipment	A micrometer on d would cut its 2.4% contribution to about 0.6%
Be more careful	Clamping against a machined stop would fix L to ± 0.2 mm
Reduce human error	Timing 20 oscillations rather than one reduces the reaction-time contribution twentyfold

Words to avoid, and what to write instead

human error	Name the mechanism and quantify it: "reaction time contributes about 0.2 s per timing"
error	Usually you mean uncertainty; error is the difference from the unknown true value
accurate	Close to the true value. Not the same as precise
precise	Tightly clustered. A systematic offset gives precise and inaccurate
roughly correct	Give the number of uncertainties
due to errors	Which error, of what size, acting in which direction

The four sentences, as a template

> Combining the contributions gives *[quantity] = [value] ± [uncertainty] [unit]*, a relative uncertainty of *[X]*%.
> This is dominated by *[measurement]*, which contributes *[Y]*% because it enters as *[power]*.
> Measuring it with *[instrument]* would reduce this to about *[Z]*%.
> The accepted value of *[value]* lies within *[n]* uncertainties of the measured value, so the two *[do / do not]* agree.

D

Forty Common Errors

Spot-and-fix. Each one is something markers see every week, and each one costs marks that had nothing to do with the physics or the engineering.

Structure (1–6)

1	Analysis in the results section. Move it to the discussion.
2	A discussion that narrates the graph instead of comparing values.
3	A conclusion introducing an idea that appears nowhere else.
4	An aim that says "investigate" and names no quantity.
5	An abstract with no result in it.
6	An abstract that's really a method section.

Method (7–12)

7	No instrument models or resolutions.
8	Dimensions without tolerances.
9	The load range or increment not stated.
10	The number of repeats not stated.
11	Present tense, or the imperative ("take five readings").
12	Discarded readings not mentioned.

Numbers and units (13–21)

13	A numerical answer with no unit.
14	No space between number and unit (4.7kN).
15	Units italic, or quantities upright.
16	°K, or Kg, or Mhz.
17	Prefixes mixed mid-calculation: mm in one term, m in another.
18	More significant figures than the data justify.
19	Rounding in the middle of a calculation.
20	An uncertainty to four significant figures.
21	A value whose precision doesn't match its uncertainty.

Tables and figures (22–30)

22	Column headers without units.
23	Units repeated in every cell instead of in the header.
24	Inconsistent precision down a column.
25	Table caption below the table (it goes above).
26	Axis labels as words (“Time”) rather than quantity and unit.
27	A scale using a third of the plotting area.
28	Dot-to-dot instead of a fitted line.
29	A gradient taken from two data points rather than from the line.
30	A gradient quoted without units.

Captions and cross-references (31–34)

31	“Figure 3: Graph of results.”
32	A figure never referred to in the text.
33	“The graph below” instead of “Figure 3”.
34	Figure numbers out of order relative to first mention.

Uncertainty (35–38)

35	Uncertainty computed and never discussed.
36	No statement of which term dominates.
37	“Human error” offered as an explanation.
38	Improvements suggested that wouldn’t affect the dominant term.

References and finishing (39–40)

39	An accepted value quoted with no source.
40	The abstract and the conclusion quoting different values, because the analysis was redone and one wasn’t updated.

Using this list

Don’t read it before writing; read it during the second revision pass from Chapter 22.

And after a marked report comes back, tick the ones you committed. Most students find the same four or five every time, which turns a list of forty into a personal list of five, and that’s the list worth keeping at the front of your lab book.

E

The Submission Checklist

Photocopy this. Run it in the last hour, in order, after you have stopped writing.

Pass 1 — Structure (20 minutes)

☐	Each rubric row can be pointed at in the document
☐	The aim names a quantity
☐	The conclusion answers the aim, in the aim's own terms
☐	Nothing interpretive remains in the results section
☐	The discussion compares, attributes, tests assumptions, accounts for anomalies
☐	Nothing new appears in the conclusion
☐	Assumptions named in the theory section get a verdict in the discussion

Pass 2 — Content (30 minutes)

☐	Every value in the abstract matches the results and the conclusion
☐	Every numerical answer has a unit
☐	Every value's precision matches its uncertainty
☐	Every table column header has a quantity and a unit
☐	Every figure has axis labels with units
☐	Every figure and table is referenced by number in the text
☐	Every gradient has a unit and an uncertainty
☐	Every symbol is defined once, with a unit
☐	No symbol means two things
☐	One sample calculation redone and it reproduces the table
☐	The dominant uncertainty is named in words
☐	Agreement is stated as a comparison with the uncertainty

Pass 3 — Surface (20 minutes)

- ☐ Printed, and read on paper
- ☐ Read aloud, at least the abstract and conclusion
- ☐ Tense and voice consistent throughout
- ☐ Captions: above tables, below figures
- ☐ Figure and table numbering sequential by first mention
- ☐ One citation style, applied everywhere
- ☐ Every reference in the list is cited in the text, and vice versa
- ☐ Spellchecked, then read for the words a spellchecker misses

Pass 4 — Submission (10 minutes)

- ☐ File format as specified
- ☐ Filename as specified
- ☐ Page limit met, counting what the brief says to count
- ☐ Name, ID, module code, date, title present
- ☐ Page numbers present
- ☐ Appendices referenced from the body
- ☐ Data or code attached if required
- ☐ PDF opened on a second machine; figures and equations render
- ☐ Submitted, receipt saved

If you only have twenty minutes

Do these six, in this order:

1. Units on every numerical answer.
2. Units on every axis and column header.
3. The abstract, results and conclusion quote the same value.
4. The dominant uncertainty is named.
5. Every figure is referenced by number.
6. The conclusion answers the aim.

Those six recover most of the mechanically available marks, and none of them requires you to think about the physics.

F

Further Reading, Honestly Annotated

Short list. Each entry says who it's for, and I've left out books I haven't used.

On technical writing

Heather Silyn-Roberts, *Writing for Science and Engineering*. The best single book in this area, aimed a level above the undergraduate lab report: theses, papers, proposals, and professional documents. Read it in your final year, and keep it afterwards.

Michael Alley, *The Craft of Scientific Writing*. Strong on sentence-level clarity and on figures, with a lot of before-and-after examples. Occasionally dated in its examples, undimmed in its principles.

Joseph Williams, *Style: Lessons in Clarity and Grace*. Not technical writing, and the best book on English prose I know. The chapters on cohesion and on nominalisation will fix more of your writing than anything on this list.

On uncertainty and data

John Taylor, *An Introduction to Error Analysis*. The standard undergraduate text, and deservedly. If you only own one book on uncertainty, own this one.

Les Kirkup and Bob Frenkel, *An Introduction to Uncertainty in Measurement*. Closer to the modern GUM framework than Taylor, and useful if your course uses the language of standard uncertainty and coverage factors.

Edward Tufte, *The Visual Display of Quantitative Information*. About graphs, and about a century ahead of the defaults in your spreadsheet software. Read it once and your figures change permanently.

On design and engineering documents

Your own institution's standards, and the relevant national or international ones. Unglamorous, and the actual answer for design reports. Find out which standards your course expects you to cite and read the introduction to one.

IEEE Editorial Style Manual, free online. The reference for numeric citation and for units and symbols in engineering documents, and a good arbiter when your group is arguing about a convention.

On typesetting, if you go that way

Gaurav Tiwari, *LaTeX for Students*. If your reports contain much mathematics, learning LaTeX in second year pays back over a thesis. Equations, figures, references and cross-references all stop being manual work.

Gaurav Tiwari, *LaTeX for Theses and Dissertations*. For the final-year project specifically: front matter, chapters, bibliography management, and the things that break at eighty pages.

The companion volumes

***How to Write Mathematics*.** For the derivation-heavy end of this book. Proof structure, notation, and writing mathematics that a reader can follow, with before-and-after rewrites.

***How to Read Mathematics*.** The other side: unpacking definitions, reading proofs and papers, and getting through a textbook chapter without bouncing off it.

***The STEM Exam Handbook*.** The same treatment applied to the exam hall: triage, timing, partial credit, and what markers can and can't award.

A Note from the Author

Thank you for reading. Books like this one live or die on word of mouth from students, so if it moved a report from a 58 to a 68, two minutes of your help matter more than you'd guess: leave a short, honest review wherever you bought it, or lend your copy to whoever in your lab group writes the discussion section.

The appendices are working tools rather than reading. The submission checklist and the uncertainty phrasebook are meant to be photocopied and kept in the lab book. You'll find printable companions and more of my writing for students at **gauravtiwari.org**, and corrections and questions are welcome there.

I'd particularly like to hear from demonstrators and lab markers about what they're really seeing on scripts. Future editions will owe their sharpest fixes to those messages.

Also by Gaurav Tiwari

How to Write Mathematics
Proofs, Papers, and Problem Sets for Students

For the derivation-heavy end of this book. Proof structure, notation, the grader's-eye view of partial credit, and the architecture of a first paper or thesis.

How to Read Mathematics
Definitions, Theorems, Proofs, and Papers for Students

A six-step drill for opening any definition, three ways to read a proof, a stuck protocol that always ends in an action, and honest reading speeds.

The STEM Exam Handbook
Timing, Triage, and Partial Credit in Maths, Physics, and Engineering Exams

The same treatment applied to the three hours in the exam hall: the four-minute triage, method marks, salvage writing, and ten annotated scripts.

Other titles

- *LaTeX for Students*
- *LaTeX for Theses and Dissertations*
- *The Student Research Workflow*
- *Indian Polity: Complete Notes for UPSC Prelims & Mains*
- *Website and Blog Copywriting*
- *The Affiliate Bloggers System*

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