Writing a research paper

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CO_2 React

Geologic Carbon Storage

A Marie Curie Initial Training Program

Writing a research paper in science and engineering

Starting to write

Experienced researchers know when it is time to write a paper. A broody scientist feels a paper taking shape and knows when there is something to say. Beginners may find the timing less obvious. My advice is to be bold and start to experiment with paper writing sooner rather than later. There are several reasons for this: first, writing is *part of the research process*, not something tacked on at the end; second, a research paper is rarely the last word, usually just a small, useful contribution which may be within your reach surprisingly early in your project; third, even if your first effort fails you will have found out why and that is good experience.

Do not expect the writing of a scientific paper to be easy or rapid. In the writing, you will look at theory and experiment, both your own and earlier work, in more detail and depth than you will have done before. You will probably make important discoveries about your own results. You may find that you need experimental data that you have not obtained. You will find difficulties in your lines of argument which you had overlooked before. Writing down a piece of science so that it holds water from beginning to end is a severe test of its quality and logic. No compromises here.

Your paper will go through at least five and perhaps ten or more drafts. Writing it will probably take you hundreds rather than tens of hours of work. It will be interspersed with more analysis, perhaps more experiments, repeats and checks, more reading and more thinking. At the end you will probably have squeezed the juice from your work in unexpected ways. The writing of the paper is at the heart of the research process.

Picking a journal

Picking a target journal is something you should do right at the beginning of the paper writing. Mainly this is because before you write you must have a clear idea of the level at which you are pitching your work and who your target audience is. The journal largely determines this. The subsidiary reason is that the minutiae of paper construction (length, format, style etc) are journal-specific.

You will know the journals which publish good papers in the field in which you are working. However there may be a dozen or more to choose from. How to choose? Start by thinking which journals have recently published work on your topic of a quality which you respect and which you think you can match. Look in detail at a few issues of the journal, preferably the paper version. Assess the range and quality of the papers published and the institutions from which they come. Will your paper look comfortable in that company? Check the names of the academic editors. Look also at the speed of publication: journals vary a lot in the efficiency with which they process papers submitted to them. Most journals show the date submitted and date accepted somewhere in the small print of each paper they publish. Ask more experienced authors what they think about the merits of different journals.

You may also wish to check the Impact Factor of the journal. This is a rough measure of its standing within a particular discipline. Look at the ISI Citation Index on the Web of Knowledge.

In building your publication list as part of your CV, you may also decide to send your work to a journal published by a professional institution in your own discipline.

Read carefully the *Instructions for Authors* provided by your chosen journal, usually available on the web.

Some journals, mostly non-commercial American journals such as those of the American Institute of Physics and American Chemical Society, levy page charges on publication, typically several hundred dollars per page. These are often waived for academic authors from outside the USA, but if you choose to submit to such a journal bring this to the notice of your supervisor or the senior author.

Overall, you are trying to find the best balance of journal quality, audience reach, speed of publication and probability of acceptance.

Pick a journal, agree the choice with your co-authors and stick to it.

Length and scope

Many scientific papers are too long. They try to say too much and what they say is poorly expressed.[1] I favour succinct statements of findings, results and propositions.[2]

[1] This is unfair only to the best.

The scientific paper is a compact and dense packet of information. If the text of your manuscript (without figures and tables) is longer than about 8-10 pages (say 2500 words) ask yourself if you really have that much to say. Try to write good papers, with high value/length ratio, rather than big papers.

Structuring a paper

The idea that a paper *has* to be made up of sections labelled: Introduction + Experimental method + Results + Discussion + Conclusions is wrong and you should avoid this. It is boring and limiting and suggests a paper written on a template. Of course, the organisation and sequence of material must follow this line of development to some extent. There must be a piece of writing at the beginning which sets the scene, explains why the work was done (a common omission) and puts it in the context of existing knowledge and previous related work. You must then describe with great care what you have done and how you have done it. The most difficult structural problems usually arise in the middle of the paper where you have to transmit a lot of dense information to the reader (new theory, new experimental results and so on) and also to provide a commentary to explain to the reader the deep significance of it all. I can't be prescriptive about this, as there are many solutions; but one solution that is often good is to do both of these things together, thus providing an interesting commentary as you proceed along with the main results. The rigid separation of Results and Discussion is generally not a good approach. Apart from anything else, it is inefficient, since the results invariably need to be repeated piecemeal within the discussion. Thus in Results: "We found J, K, L"; and later in Discussion: "As we said earlier, we found J, which of course shows M".

Finally, at the end you need some sort of a wrap-up or conclusion. Conclusions provide plenty of scope for tiresome repetition. In my view the only purpose of a Conclusions section is to state succinctly the main claims of the paper and collect these together in one place. Then both authors and readers know unambiguously what is claimed. Otherwise readers may have to play hunt-the-thimble. (These same conclusions probably appear, more briefly, in the Abstract. Please check that they do, or something is wrong: most probably you have not written a good Abstract).

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[2] My papers have become shorter over the years. The joint papers in which I was lead author tend to be shorter than those in which I was a co-author.

Paragraph analysis

A typical scientific paper consists of 20-30 paragraphs of text. It is useful to think of the paragraphs as the main units from which you build your paper. It is often revealing to do a *paragraph analysis* while you are writing the paper: summarise in a single sentence or phrase the content of each paragraph and check that there is indeed a clear step in the content and logic between every paragraph and the one that follows. It is surprising in a draft paper how often this is not the case. Ensuring that the content of the paper "steps" from paragraph to paragraph will make your paper much more intelligible.

Formats, packages and editors

If your paper is by and large plain text, by all means use MS Word. If there is any complexity of typesetting, especially a lot of mathematics, I strongly advise you to use Latex (see **Mathematics** below). Latex also allows you to handle literature references and internal cross-references in a much more automated way than Word.

For really complicated documents such as books and theses, use Latex. Its ability to handle cross-referenced material such as equation numbering, figure numbering and referencing is invaluable (see **Mathematics** below).

Camera-ready copy

Try at all costs to avoid publications which require you to provide camera-ready copy. You are a researcher and should not spend your valuable time as an unpaid printer and designer for the publisher. You are probably not much good at either and even if you are the other contributors to the journal, book or conference proceedings will not be.

Co-authors

These days most papers involve a co-author, sometimes several, occasionally many.[3]

Deciding who the authors of a paper should be is sometimes obvious, but not always and can be a delicate matter. There are no hard and fast rules, and practice may differ from field to field and from research group to research group. My own practice is based on a guiding principle which is that co-authors must be involved in *authorship.* Ideally all co-authors should

[3] Paul Barnes (*Inaugural Lecture* 1997): "I have written 120 papers with 150 co-authors, of whom I have actually met at least 100". It is generally a good idea to know your co-authors.

participate actively in the writing process. If they don't, they must have made a substantial contribution to the work reported and must accept full joint responsibility for the content of the paper as published.[4]

It follows that you must be scrupulous in involving your co-authors right through the publication process. In a perfect world, all the co-authors should be completely familiar with the entire paper as published – a good test is to wonder if co-author X understands the paper well enough to give a short talk on the paper (the whole paper, not just his or her bit). If X doesn't then perhaps X should not be a co-author but should instead be acknowledged for a specific contribution to the work.

Good research papers are never written by an authors committee. In my experience there is always a lead author, although occasionally two people can work closely together and act as the writing team. The lead author is usually (not always) the person who did a large part of the underpinning research. Occasionally the lead author is the synthesizer in the team; this is often the senior academic. Quite often the writing team is the junior researcher who did most of the work and the supervisor.

What can you do as a co-author?

If you are a co-author rather than the lead author, my advice is to be interested, enthusiastic and involved. Support and don't harass the lead author. Perhaps try to find a specific support role. You may be good in trawling the literature or doing the graphics or helping with the English. However the most valuable thing you can do is to promptly read incoming drafts and suggest constructive improvements by return of post.

The order of names in the author list

This is another tricky area, where practice also varies widely. My own is to put the lead author first (this is the person who has led the writing process and usually has made a major contribution to the work reported), followed by other authors in alphabetical order.[5] Some people put all authors in descending order of importance of their contribution. In my experience this tends to cause arguments. The first name is definitely privileged, since a multi-author paper will be known for ever as Parsnip et al. 2003. However

[4] It is unprofessional to let your name appear as a co-author on a paper which you have not been actively involved in writing, or conversely to put others in this situation.

[5] My DPhil supervisor Rex Richards took a relaxed and egalitarian view of things and in his research group authors were always listed in alphabetical order. I followed this innocent practice for a few years, but it is uncommon and in the end I decided it was fairer to put the main contributor's name first.

once the lead name is agreed, there is little benefit in jockeying for the other positions.

You should resist if possible any editorial interference with your agreed author-list order. Some journals like to group authors from the same institution but you should object to this if it drives a coach and horses through your carefully negotiated author-list.

Sole authorship

Once in a while you should try to write a paper entirely on your own. There are good academic reasons for this. Academic committees and panels are always struggling with the problem of how to assess the individual contribution to team research. A sole-author paper is the one case where this is crystal clear. It is also good to take a paper right through the publication process yourself. If you feel that the work is essentially your own, do not hesitate to publish it as your own. There is no automatic need to add your supervisor's name (although you should certainly discuss this with him/her: in general, secrecy is a bad idea in matters of academic publication). Early in my career as a postdoc I wrote a short paper and sent it to my professor for his approval, with both his name and mine as authors. He wrote back generously to say he liked the manuscript but felt he had not contributed much to it and I should publish it myself.[6]

Affiliation

The rule is to associate the work reported with the institution in which it was done. Since many academic scientists are nomadic, the current address of an author may be different. Usually this is dealt with my adding a "Now at: University Q" footnote.

However this simple rule is not really so simple, as two cases show:

- If the lead author moves to a new institution N+1 and spends many weeks writing a complicated paper based on work done at institution N, it is reasonable for him/her to give N+1 as affiliation. Ideally, the support of N should be noted in the Acknowledgments, but this is rarely done.

- The lead author must not give the impression of being affiliated to an institution N from which he/she has long since departed, particularly if

[6] The counter-position of some senior academics is: "This paper is an output of my research group/laboratory/institute and the work could not have been done without the facilities, intellectual and material, which I provide. Therefore my name goes on every paper published."

he/she is the only author with that affiliation. The solution is probably to co-opt a friendly co-author from N and always to indicate a current address, even if this is a private street address rather than an institution or company.

Affiliation needs sensitive handling. The underlying principle is to give due credit to the institutions which have provided a home for the work, both the research and the writing. Institutions get real value, credit and resource from your paper, and you owe them a fair deal.

Acknowledgments

Be generous in recognising the contributions of others to the work reported. These can be of several kinds: support activities such as technical and computing work; notable intellectual contributions from other individuals through discussion and consultation; industrial support; institutional and agency funding; any and all collaborations which do not amount to co-authorship.

Ethical issue: some people are extremely sensitive to perceived slights which arise from lack of acknowledgment. In extreme cases, this can lead to serious disputes which are time consuming and stressful. Err on the side of generosity in acknowledgments and think back carefully over the history of your research to avoid overlooking significant contributions. Do not fail to recognise the use you may have made of other people's software, experimental equipment and materials.

Don't hesitate to discuss the drafting of an acknowledgment with the people concerned. Once it is in print you're stuck with it, so get it right.

Style point: avoid flowery language in acknowledgments. You can say all you need to in a few words.

> We thank Adam Smith for luminosity data; and ABCD for financial support.

Title

Be clear and informative. A common error is to write a title which is too broad in scope and which lacks specifics. Thus the second of these is much better than the first:

> Studies of the wettability of calcite.

> Dynamic contact angle of C_4-C_{10} alkanes on calcite at 5 °C.

There may be strict limit on title length. You should aim for the shortest title you can achieve without sacrificing precision.

Some journals do not accept multi-part paper titles:

> Capillary studies in zero gravity. Part 24, Wettability of quartz.

Author names

Take advantage of the trend to give authors their full first name: John F Kennedy, rather than J F Kennedy. The full name is clearly a better identifier. But try to be consistent from paper to paper in the form you use for yourself. It confuses search engines and readers to find W Shakespeare, William Shakespeare, Will Shakespeare (and W J Shakespeare) coming and going in the literature. Are they the same person?

Abstract

The abstract is a completely separate thing from the paper itself. Don't give any thought to the abstract until the paper is finished. Because the abstract is usually printed at the top of the paper, it is a common mistake to mix up the abstract and the introduction.

Remember the purpose of the abstract. The abstract is a terse summary of the contents of the paper. It stands alone. It is used by bibliographic databases and search-engines; it is read by people who don't have access to the full paper and used by them to decide if the full paper is worth getting. In writing the abstract you are aiming for maximum information content; it should be strictly factual; avoid opinion; include key numerical data. If you have measured X or proved Y or discovered Z, the abstract should say just that. Think of it as the <u>capsule</u> form of the paper.

There should never be anything in the Abstract which is not found in more depth in the full paper.

There is usually a strict limit on the length of the Abstract, commonly 100 or 150 words. Here's an example of a satisfactory Abstract, which happens to be 148 words:

> Energy-dispersive diffraction tomography using white-beam synchrotron x-rays with energies up to 140 keV yields images of the interior features of solid objects up to 50 mm thick. The volume sampled is determined by the geometry of the diffracting lozenge defined by the incident beam, the detector system collimation and the Bragg angle. Using conventional beam slits to form a highly collimated 50 μm × 50 μm incident beam and a 40 μm collimator aperture, we demonstrate on a PEEK phantom that a lateral resolution (transverse to the beam direction) of a few microns can be

achieved. The resolution in the direction of the incident beam is necessarily poorer than this since the diffracting lozenge is elongated in this direction, with length increasing rapidly at small angles. There is no evidence of significant contamination of the diffracted intensity by the effects of multiple scattering from outside the primary lozenge.

References

The scientific literature is a vast network of cross-citation. In writing your paper you are contributing to this and one of your main responsibilities as an author is to make sure that you place your work correctly in relation to work previously published. This is no small task. You need to observe the conventions which have been established over many decades for citing the work of others.

You have an absolute responsibility to acknowledge all other publications on which your work directly depends. Some judgment is necessary here, but you must cite enough of the existing literature to show that you are thoroughly familiar with it. It is a serious sin of omission to fail to mention a paper which deals with matters close to those you cover in your own paper, whatever your opinion of that earlier work. Authors of uncited work may feel snubbed and in a bad case you may even have to write to the journal to admit to having overlooked a prior publication. The moral is to do your homework scrupulously.

Do not cite any reference which you have not read (or put differently: make sure you have actually read all the references you cite).

You must list references to previous work using the precise format prescribed by the journal in its Instructions to Authors. There is *no* standard format, although many are closely similar. Because different journals use different formats, your research bibliography (however you keep it) should hold full information on the reference. In particular, you should have the full name of the journal, the first and last page number of the reference, and the paper title and author names (letter perfect, not just an approximation). For books, you should hold also the publisher name and the place of publication; for conferences (the most troublesome category), you should keep the full details of conference title, paper title, sponsoring organisation, date and place of the conference, and the date and place of publication. It is common for your journal editor to query an item in your list of references, so have the full back-up information to hand.

Remember that the scientific literature predates the search engine. In many fields there is work of high quality in the period, say, 1920-1970 which deserves your careful attention. But don't be pretentious and cite nineteenth century French masters on the foundations of thermodynamics (even if you have read them, which I doubt): cite instead a really good modern textbook which covers all the mainstream fundamentals.

I find it useful to sketch a literature map, which consists of a single sheet of paper on which you note the main topics of your paper, and the key half dozen (not more) references for each of these topics in order of publication date. Draw in the linkages and dependencies between them with squiggly lines. This gives you a kind of map of the literature which shows the main towns and cities and captures the key features of the geography. You can add more detail if you want to, and make larger scale maps of smaller areas.

Make sure your references are correct in every detail. My experience over many years of refereeing papers is that the references list of most manuscripts is riddled with errors.[7]

Your working collection of published research papers will mount up quickly, so that your personal research bibliography may reach many dozens of items in a few months and a hundred or more in the course of a postgraduate project. It is useful to have a simple tagging system for research papers. I have a simple method which works well and provides a short tag for every paper in your collection. Thus the publication

Camuffo D, Del Monte M, Sabbioni C and Vittori O. Wetting, deterioration and visual features of stone surfaces in an urban area. Atmospheric Environment 1982, **16**, 2253-2259.

is tagged CamuffoDSV82, the tag comprising the first authors surname, the first letter of the surnames of the co-authors (up to a maximum of three) and the last two years of the date of publication. It is unusual for a group of authors to publish more than one publication in the same year with the authors in the same order. In the unlikely event that they do, then we tag the first CamuffoDSV82a and the second CamuffoDSV82b. I use this for filing papers (both paper and e-copies); and also in Latex documents for tagging items using the `\bibitem` method. You can add references in papers in draft in an unambiguous way.[8]

In your final manuscript, you will have to cite references in the text according to the journal's strict format, which will either be a number system or the so-called Harvard author-date system. Whichever you need to use in the final version of the manuscript I strongly recommend that you use an author-date system while you are writing. It is easy at the end to convert an author-date system to numbers, but if you use numbers from the beginning you face a nightmare each time you add a new reference and all previous references need renumbering. I use tags such as CamuffoDSV82 while I am writing. In Latex, this problem is largely circumvented by automatic tagging.

[7] Theses also, please note. I promise to find an error in your list of references.
[8] Applications such as Endnote can be used to organise bibliographies.

Peer review and referees

Peer review of your paper can be painful and unpredictable, but don't be too negative about it. Learn to enjoy it. It is a proven means of improving the quality of research papers. It often picks up errors and weaknesses in a paper which really need correcting and everyone benefits from that. It is also satisfying and a comfort to have met the demands of independent experts and received some sort of seal of approval.

Referee comments may be wise, friendly and illuminating. More often you will think they are eccentric, bizarre, unfriendly or plain ignorant. Even so, always deal with them courteously and patiently. Be prepared to make adjustments where you can, but hold your ground on points of substance and argue these carefully and fully. Try to see the text from the referee's point of view: his/her objection is probably the result of something unclear (or even wrong!) in your text rather than pig-headedness or hostility. In any case, the referee always has the upper hand and nothing is to be gained by falling out.

Just occasionally, a referee can be really troublesome and the author becomes embroiled in a long series of unproductive exchanges. This sometimes happens when a referee misunderstands the purpose of peer review and wants to take your research over. The reviewer says: "You have reported a piece of work X but I think you should have done Y"; or "You have reported X which is OK as far as it goes but you should now do Y". Both positions can be unreasonable and in the last resort you can appeal to the journal editor to break the impasse. I have known such problems arise but they are rare and I have never run into them in publishing my own work.

Most peer review is anonymous. It is only human to try to work out who the reviewers are and much forensic effort goes into this. It is quite enjoyable to do this, but only for recreation.

You may be asked by the journal at the time of submission to suggest the names of possible referees. Take advantage of this, but don't try to use it to circumvent serious review by nominating your friends or friends' friends.

Support material and data archiving

Ideally for every paper published there should somewhere be an archived file containing the data, the calculations, the software, laboratory notebooks; together with the paper drafts, referee comments, editorial correspondence, copyright forms etc.

This is a counsel of perfection, and I don't believe the audit trail commonly exists, at least in a tidy and organized form.

Even so I think it should and in my own files it usually does.

There are two main reasons, one public and one private. The public reason is that in publishing your research paper you are declaring certain things to be so and you should be in a position to support the claims you make.[9] You will rarely be required to, but there is a strong "good practice" case for being able to. There is no doubt that researchers in science and engineering are much more aware of the possibilities of fraudulent practices than in the past.

The personal reason is equally strong. The person most likely to be interested in the future in the archive file is you. In five years time, you may wish to write a review article drawing on the work you are now reporting; later you may wish to write a book on the subject. It is extremely valuable to be able reliably to recover data, mathematical analysis, software code and output, graphs and diagrams from your own personal archive.

Writing style

I am not writing a style manual, so the hints that follow are just hints.

Your style is your own.[10] But however individual, a good writing style for a scientific author must work at several levels: you must at least think separately about the architecture of the paper and the words you use.

I put high value on clarity and brevity. I want the structure to lead the reader through the material presented.

I ask every word to pay its way. It is rare to find a draft which cannot be improved by deleting weak words;[11] but rare also to find a draft which cannot be improved by adding real content.

I like the first person and the active voice. Not everyone does, so I don't force the issue; but if you do use the active voice ("We have studied J; we find K; our experiment shows L") you will have a simpler syntax.

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[9] Most academic research is ultimately supported by public funds and the results of research are in some sense publicly owned. Research contracts today usually require investigators to disseminate research *findings*, but it is likely that investigators will be required increasingly to make *primary research data* publicly available.

[10] Lead author and co-author can fall out over style issues. More commonly, they don't fall out, but style conflicts are unresolved and the co-author's pleasure in the published paper is diminished by a lasting sense that the paper "wasn't well written".

[11] Henry Edmundson, an experienced science writer and editor, told me he removed all occurrences of the word "very" from articles he published. I find this is ~~very~~ good advice, although there are rare cases where "very" can be useful.

If English is not your first language (and even if it is), please find a native English speaker to read through your text.

Remember also that English is not the first language of many of your readers. This is one of the main reasons to strive for simple, clear expression in your text. Do not use obscure words if simpler ones exist; do not use difficult grammatical constructions where they can be avoided.

Jokes do not sit well in scientific papers, but there is no reason to plod along and write wooden English. Try to avoid too many conventional phrases, dull constructions, overworked adjectives (findings need not be *novel*, methods *robust* …) and tired verbs (our problems need not invariably be *addressed*...?).

Fowler's Modern English Usage (the new edition by Burchfield) is a good guide to English usage (both British and American English); this and a dictionary such as the Oxford provides most of what you need. Please use a dictionary, not just a spell checker. Spelling errors are now universal, especially cases such as *principal* and *principle* which a spell-checker seems too dumb to catch. At the back of these notes I have listed a few style guides, of which the Oxford and Chicago books are widely used by publishing professionals.

Quantities, symbols and units

This seems to cause endless difficulties but it shouldn't. Most of science and engineering consists of statements about physical quantities. If you understand the essentials of *quantity calculus* then most of the difficulties disappear.

Quantity calculus. Physical quantities are things like force, mass and time. There exists a small number of independent physical quantities and the only system you really need to know about is the SI system. Other quantities are derived from these by equations such as $F = ma$.

Physical quantities have preferred symbols (P for pressure ...) and recommended units. Follow carefully the recommendations of the journal in these matters. Try to be consistent in the choice of symbols in your own papers. Symbols are printed in italics.[12]

Experimental measurements and theoretical calculations usually provide values for physical quantities under particular conditions. The value of a physical quantity is always expressed as the product of a number and unit.

[12] There are rare exceptions: for example, dimensionless groups such as the Reynolds number Re are printed in upright Roman type.

For example if we use the symbol P for the pressure, and we measure or calculate a particular value of the pressure we can write

$P = 3.176$ atm

where we are using atm as the unit of pressure.

We can equally write

$P/\text{atm} = 3.176$

and it is this number that we plot on a graph or put into a table. Therefore the graph axis or the table heading should be labelled P/atm.

We can easily change units. So for example

atm = 1.01325 bar

and therefore

$P/(1.01325\ \text{bar}) = 3.176$

so that

$P/\text{bar} = 3.218$.

For the physical sciences, I recommend the little book by M L McGlashan: Physicochemical quantities and units: the grammar and spelling of physical chemistry, Royal Institute of Chemistry 1968; and by the same author Manual of symbols and terminology for physicochemical quantities and units, Butterworth 1970. These are old but excellent.[13]

Mathematics

Mathematical typesetting, both its syntactic and its graphic aspects, is a huge subject, on which whole books have been written. In earlier times it used to be a highly skilled practical task for scientific publishers and printers, about which the author had to know little. Much of the responsibility for this now seems to fall on the author.

If your paper contains only a little mathematics you can probably fumble through with a standard word-processing package and rely on the publisher

[13] The current equivalent is the IUPAC Quantities, Units and Symbols in Physical Chemistry ("The Green Book"). Third Edition published in September 2007. The earlier Second Edition is available on-line http://www.iupac.org/publications/books/gbook/green_book_2ed.pdf. Other subject areas and their leading scientific societies and institutions provide similar guidance.

to make the finished job look good. However in my experience, most writers of scientific and technical papers who regularly publish papers which contain a fair amount of mathematics use Latex. Using Latex allows you to achieve an extraordinary quality of mathematical typesetting without worrying at all about the mechanics of the layout on the page.[14]

You will have to make a serious investment of effort to become competent in using Tex/Latex, but it is probably worthwhile if you expect to be engaged in scientific and technical writing long into the future. Tex/Latex format sets the standard for electronic submission throughout most of physics, all of mathematics and much of engineering. The large institutional scientific publishers such as the American Institute of Physics, the Institute of Physics in the UK provide Tex/Latex templates for authors.

The Tex bible is Knuth's The Texbook. Latex is a Tex-based system developed by Lamport, and Latex2e is the current version. There are many guides. If you are really interested in the maths, the AMS Guide to Tex is valuable. MikTex is a high quality Latex package for Windows available as freeware; it requires a Latex-oriented Windows text editor such as WinEdt (shareware). I think the MikTex/WinEdt combination works outstandingly well (see www.winedt.com for all you need).

Remember also that:

- Displayed equations are treated as parts of sentences for purposes of punctuation.
- You should display (and number) only those equations which you refer to later or which are too large and elaborate to embed in the running text.

Figures: graphs, diagrams and other graphics

The figures are often (and usually should be) among the highlights of your paper. Therefore, spend a lot of time getting them right. Traditionally, a figure in a research paper was either a black-and-white graph or a black-and-white line diagram. This remains broadly the case today, although the variety of graphics in research papers is becoming wider. You can take advantage of this, but cautiously. Journals deeply dislike fancy artwork from their authors. You should conform to the usually conservative house style. Journals are becoming more willing to consider colour and to pay for it, but this is not the norm yet (see your target journal's Instructions for Authors).

Graphs for scientific research papers are not the same as presentation graphics. Don't for one moment think of using Powerpoint to produce

[14] Of course Tex and Latex are much more than this and provide a way to produce entire documents (notably books and theses) of outstanding design.

research paper *graphs*. Powerpoint can however be used successfully for *diagrams*.

Since black-and-white figures are the norm, you lose all the colour coding you are used to having on your computer screen and in presentation graphics. This means you have a limited range of symbols (• ∇ ...) and line styles available to you.

Graphs should be drawn using a high quality scientific graphics application. These days I invariably use Matlab,[15] in which the graphics environment provides complete control of the output. My five tips about graphs are

- Make the symbol size, font size and line thickness large enough to survive the overall reduction in size on printing. Symbols and line styles used to represent data in more than one figure should be consistent if possible.
- Use a sans-serif font such as Arial or Helvetica for all figure labels.
- Strip all unnecessary text, legends and annotation out of the graphic. Most information should be in the figure caption and not in the graphic itself.
- Fix the axis ranges to spread the data over the plot area; avoid large areas of white space.
- Fix the aspect ratio (width/height) of the figure to look good on the page. This usually means roughly square or portrait for a two-column journal format; or square or slightly landscape for a single-column format.

If you do work in the Matlab graphics environment, the entire graph can be created using a Matlab script. Changes can then be made by editing the script at any stage. Complex graphs can then be built up, including multiple plots, curve-fitting, labelling etc. Matlab supports Tex/Latex format for Greek symbols, subscripts, bold/italic fonts for example for axis labels.

If you are working in Latex, you need Postscript graphics.

Remember, the publisher will tidy up your text, but the graphics will appear exactly as you produce them (apart from reduction in size). You should devote a lot of time to getting the graphics right.[16]

Proofs

It is quite a triumph to get a scientific paper into print without a single typographical error. The typesetting of a research paper is often complicated and minor typographical errors are hard to trap. Some people are much better at finding them than others. It is always good to get more than one person to

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[15] There are no doubt several others, of which I am dimly aware of SigmaPlot and gnuplot. But please don't use Excel.

[16] For the first paper I published, my rough figures were completely redrawn by Cambridge University Press. Those were the days.

check the proofs. It is essential to get all your co-authors to check the proofs. If you do not, they will blame you for the inevitable typographic error(s) they will find after publication. Share the responsibility. It is even better to get a non-author to read the paper for errors as well.

Journals and publishers also vary greatly in the level of careful copy-editing which they provide. There are excellent editors in a few journals, but you cannot depend on this unless you have worked with a particular journal before and know them.

Authors are always strongly discouraged by the publisher from making changes to the text at proof stage, but don't be too alarmed by this stern prohibition; in my experience small changes (single words, perhaps the addition of a sentence here or there, or even a reconstructed paragraph once in a while) will not be resisted and it's important to get your paper right. You have only one chance.

It is extremely difficult to get publishers to supply second proofs (that is, proofs of the corrected copy). However if the first proofing involved corrections of any complexity, you are advised to try hard to get the publisher to send second proofs to you.

If you have paper proofs to correct, use standard proof-correcting symbols if you can, but don't worry too much about these funny signs – aim for clarity, strike out the error and write the correction clearly in the margin. Keep a copy of your corrected proof.

After proof correction, many journals now publish the paper on-line before it appears in a print issue. This on-line version is is dated and its on-line appearance constitutes formal publication of the work. At this point, the paper is usually assigned a DOI: a Digital Object Identifier. This is a unique label which allows your work to located on digital networks. Increasingly the DOI is used in citations to provide a hyperlink to the paper or at least its bibliographic record. You should therefore now note the DOI in you own publications lists. For more information, see http@//www.doi.org/

What to do if your paper is rejected

Of course it is a pleasure to have a paper accepted. A few prestige journals have low acceptance rates[17] and it is particularly nice to see your work published in one of these. However most journals are not in that select group and publish a fairly high proportion of the work they receive. Therefore if

[17] *Nature* publishes only 10 per cent of the already highly pre-filtered work it receives. However many middle-of-the-road scientific journals accept at least half the work they see.

your research is of at least reasonable academic quality and the paper carefully written you should expect to get it published.

What can you do if it is rejected?

First, analyse the grounds for rejection. You must reach one of two conclusions. Either your paper was rejected because the work was not good enough to be published; or the work was fine but you sent it to the wrong place. Either way, you've a lot to do.

If the paper was below par in quality, then you should probably count yourself lucky it was not published. Go back to the drawing board and continue your research. When you have made more progress, you should write another paper from scratch. Your old manuscript is not a good starting point. Put it in the bin.

On the other hand if you want to submit to another journal, first reflect on why your first choice was wrong and then try to improve your targetting. Ask more experienced colleagues why you got it wrong. When you've chosen your next target journal, you will discover that, unfortunately, you will have to reformat and often rewrite your paper. It is almost impossible to resubmit the same manuscript unchanged to a different journal.

Writing a paper for a conference

This is quite a different undertaking from writing a journal paper. Usually you will have offered a contribution through some kind of "Call for papers" many months (perhaps more than a year) in advance of the date of the conference. The only sensible approach to such a long-term commitment is to decide that you will present *either* some work in progress *or* some small interesting item of research which you have not published elsewhere. On the whole, it is well understood that conferences are the place to talk about work in progress, to give some early but probably incomplete results and to let people on the conference circuit know what you are doing. This is significantly different from submitting a completed piece of work for peer-reviewed journal publication.

However, a note of caution: different subject areas use conferences differently, and in a few subject areas conferences are important publication outlets for definitive reports of new work. So, discuss carefully with your supervisor and senior colleagues what exactly is appropriate content for a conference paper in your field.

In any case, the abstract will almost certainly have to be written before the paper. This contradicts my golden rule for journal papers that the abstract should be written last! As a result, for a conference you submit an abstract which describes work you have not quite done yet. This is unsatisfactory but unavoidable.

Conferences operate a wide variety of refereeing policies, ranging from essentially no reviewing to full peer-review.

Some supplementary material

Graphics: examples

Books on writing scientific papers

Maths and equations

A few easy pieces – test yourself on these

Graphics: examples

First, let's see a good example of plotted data. Note the font and symbol sizes, line thicknesses and line styles, and axis labelling. Here, the two groups of data are referred to different y-axes. This achieves a better use of space and allows two datasets to be placed in the same figure for easy comparison. Note also that much of the information is in the caption, which is where editors like to see it.

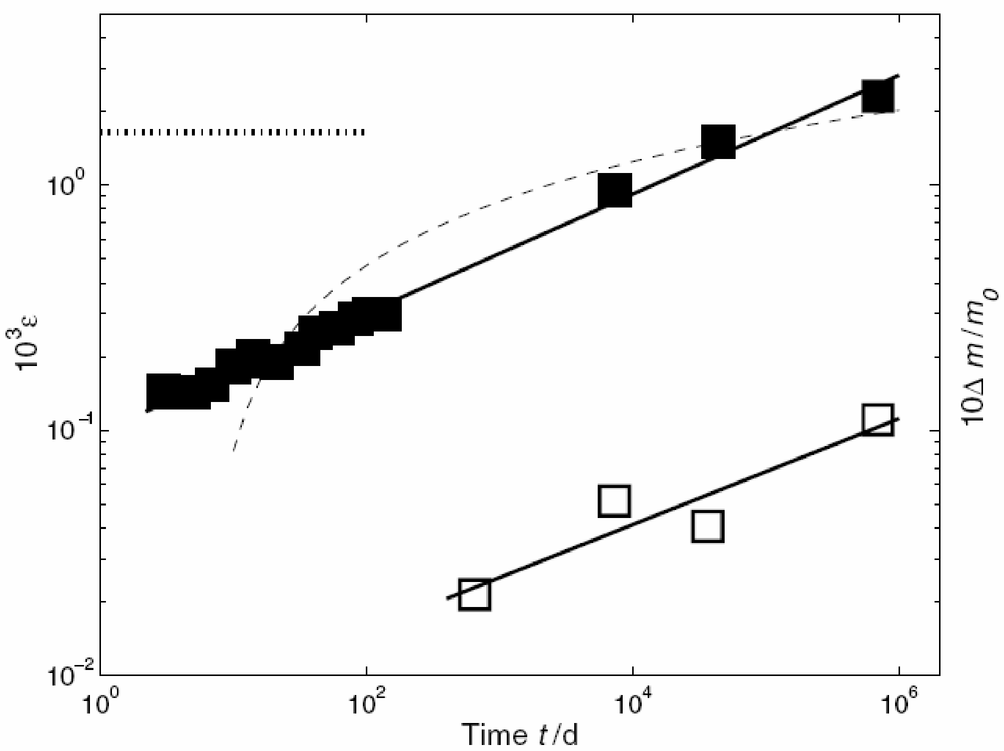

FIG. 4. The total expansive strain ϵ (solid squares) and fractional mass gain $\Delta m/m_0$ (open squares) from the time of original manufacture for bricks tested. The power-law regression equations are $\epsilon = 9.87 \times 10^{-5}(t/d)^{0.24}$ and $\Delta m/m_0 = 5.7 \times 10^{-4}(t/d)^{0.22}$ where t is the time. The dashed curve is the best fit logarithmic function. The dotted horizontal line shows the strain produced by autoclaving a freshly fired brick as in Fig. 2.

[From Wilson et al., Physical Review Letters 2003, **90**, 125503]

Second, a decent example of a complex graphic. Note the Arial sans serif font, the font size, the line thicknesses, and the density of information (not much white space). This graphic was produced in Matlab. Note also that much of the information needed to understand the figure is in the caption.

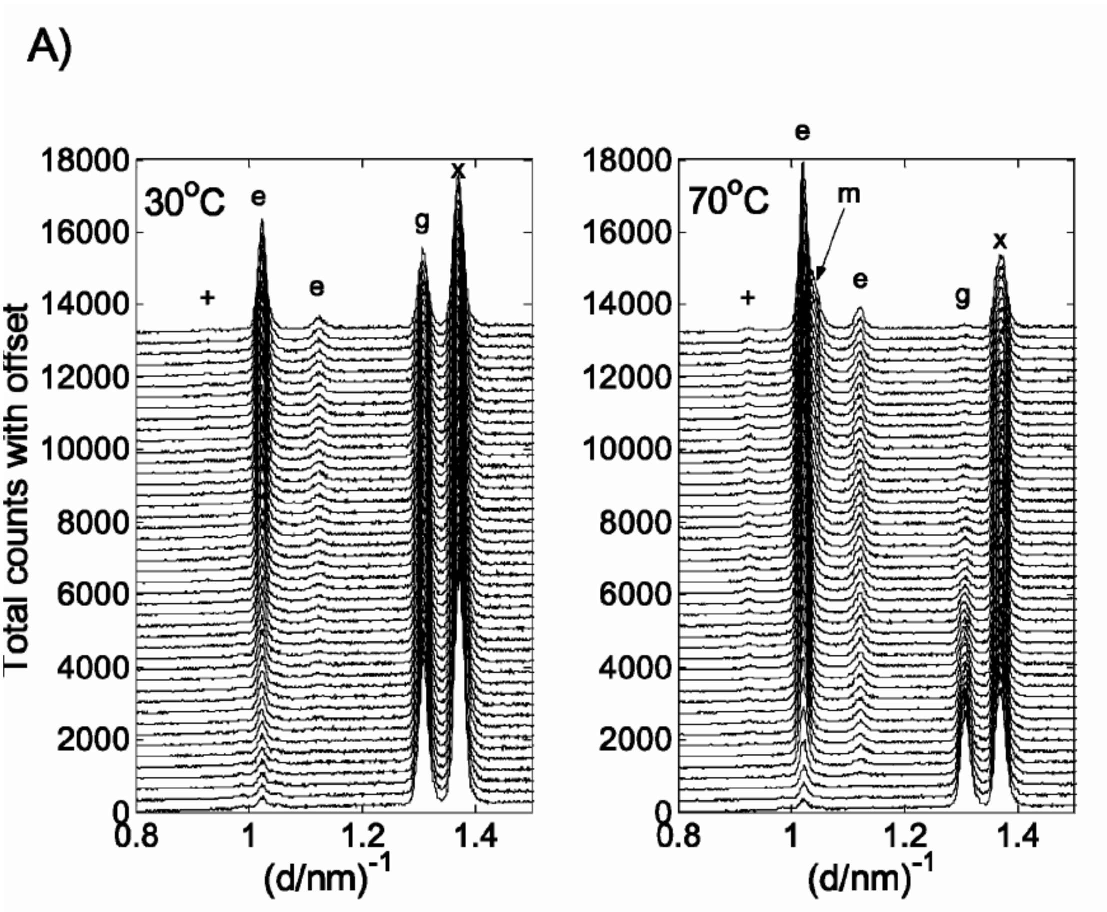

Fig. 3 Hydration of C_4AF + gypsum at 30 and 70 °C. The sample heated to 70 °C was ramped over 2 h and then held at the final temperature. Ninety patterns were collected, one every 2 min. A) Synchrotron diffraction data illustrating mineralogical changes over a 2 h period. Key: as Fig. 2 and g = gypsum; e = ettringite; m = monosulfate-14. B) Areas of the C_4AF (020), gypsum (020) and ettringite (100) peaks at 30 °C. C) Areas of the C_4AF (020), gypsum

[From Meller *et al.*, Journal of Materials Chemistry 2004, **14**, 428-435]

Books on writing scientific papers

Texts

There are quite a number of books on scientific writing, but I cannot recommend many of them. You may find the following useful:

Robert Day and Barbara Gastel, How to write and publish a scientific paper, 6th edn, Cambridge University Press 2007.

Style guides

Top of the tree in science publishing:
American Institute of Physics, AIP style guide [download from http://www.aip.org/pubservs/style.html]

Used by editors and publishing professionals:
R M Ritter, Oxford style manual, Oxford University Press 2003.
The Chicago manual of style, 15th edn, University of Chicago Press 2003.

Maths and equations

Here's a block of well presented mathematics (from a journal of the Institute of Physics, which does such things well). The manuscript was prepared in Latex. Note both in-line and display equations and the use of punctuation in the display equations.

Eliminating p_a, p_0 and x_f and putting $\theta_w = f$ in the expression for S gives

$$\frac{\mathrm{d}i}{\mathrm{d}t} = kfp_f\left[\frac{\lambda i_L - i}{\lambda i(i_L - i)}\right] = \frac{S^2}{2}\left[\frac{\lambda i_L - i}{\lambda i(i_L - i)}\right]. \qquad (4)$$

The structure of this equation is clearer if we use the scaled variables $X = i/i_\infty$ and $T = S^2t/i_\infty^2$, in terms of which equation (4) (inverted) becomes

$$\frac{\mathrm{d}T}{\mathrm{d}X} = \frac{2X(1-\lambda X)}{1-X}. \qquad (5)$$

On integration, we obtain the Sharp Front imbibition equation,

$$T = \lambda X^2 - 2(1-\lambda)[X + \ln(1-X)]. \qquad (6)$$

At early times ($X \ll 1$) equation (6) reduces to $T = X^2$, so that $X = T^{1/2}$, as in the case of unsealed absorption. At longer times X approaches the limiting value of 1 as i approaches i_∞.

[From Ioannou *et al*., J. Phys. D: Appl. Phys. 2003, **36**, 3176-3182]

Are there any typographical errors in this as printed?

A few easy pieces – test yourself on these

- Make a list of journals in your own field, and rank them in order of quality or esteem. Then go to the ISI Citation Reports and check the ranking of these journals. [For the Citation Reports, log into the ISI Web of Knowledge via the University Library].

- Select a few journals which you read regularly (do you read *any* journals regularly?) and estimate the speed of publication based on "date received" and "date published" information for each in a recent issue.

- Take a research paper with which you are familiar and write an abstract of it in a maximum of 150 words. Compare your abstract with the authors' abstract as published. Now rewrite the abstract in just 100 words.

- Pick a few research papers you are interested in. Look carefully at the titles. Do they describe the content of the paper as accurately as they should? Try to write a better title for each.

- Take a scientific paper on your desk and make a critique of the graphics in it. How do you think the authors produced these graphics? Do you know how to do as well – or could you do better?

- Take a scientific paper on your desk and review the references list: can you find errors in it?

- Take a scientific paper on your desk and review the printing of mathematical symbols and equations. Can you find errors, or poor practice in design and layout? Are the display equations punctuated as sentences? Do you think the choice of in-line and display formats is appropriate? Are symbols and units appropriate and consistent?

- Choose a journal that you would consider submitting a paper to, and download the "Instructions to authors". Read these carefully. What is said about (1) graphics; (2) units and symbols; and (3) references? Is it consistent with my advice?

- Take 10 good papers from your research collection and see how many of them use the first person and active voice in the text ["We …"].

- Carry out a *paragraph analysis* of a draft paper that you are working on (or alternatively of any published paper that interests you).

[end]