MANCHESTER 1824

The University of Manchester

How to Write Scientific Papers

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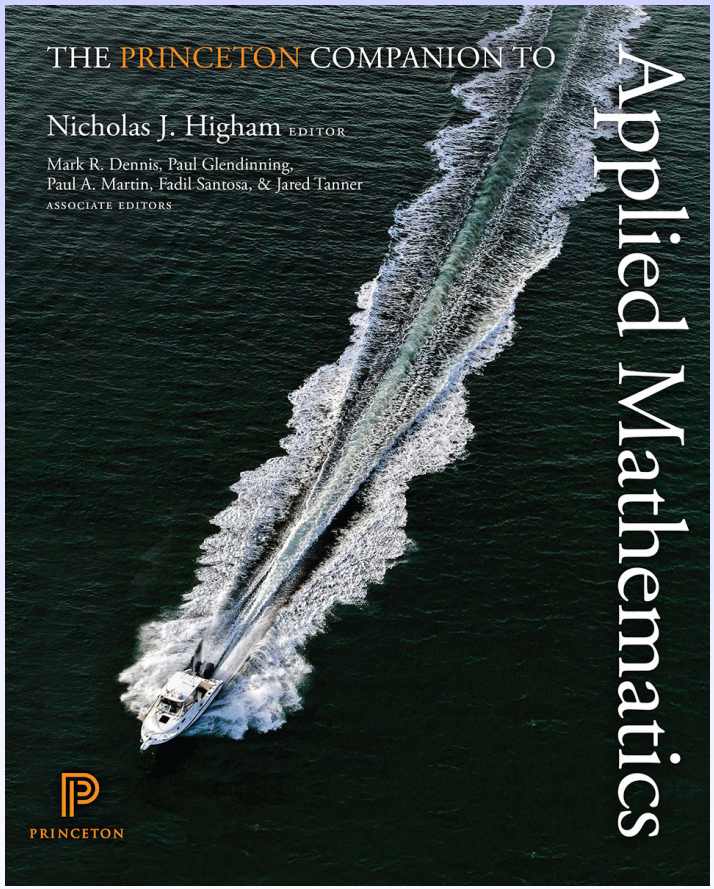
Outline

For Examples of Good Writing & Typesetting

The Princeton Companion to Applied Mathematics (PCAM)

Pages	xvii + 995
Articles	186
Authors / countries	165 / 23
Figures	196
Cross references	733
Index pages / entries	33 / 2842



Why is it Important to Write Well?

- Promote your research (globally).
- Persuade the reader to agree with your views.
- Improve chance of your papers being published.
- Help your papers be read.
- Demonstrate your communication skills.
- Feeling of satisfaction from job done well.

Most worthwhile careers involve writing!

What is Difficult?

- Having something to say.
- Getting started (see next slide)
- Improving a draft.
- Convince reader of value of your work.

Less difficult:

- English grammar.
- Maths-specific writing.
- LaTeX.

Getting Started

- Start writing **earlier** rather than later: writing is part of the process of understanding.

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- Start writing **earlier** rather than later: writing is part of the process of understanding.
- **Procrastination and writer's block**:
  - Plan and write first in your head.
  - Lower your standards until there is no threshold to go over in writing. Just start typing!
  - "The poor words may be the necessary path to the good words" (R. P. Clark).

Begin Sentences with Subjects and Verbs

R. P. Clark:

- Make meaning early, then let weaker elements branch to the right.
- Don’t separate the subject too far from its verb.

Example

"Motivated by the works of Feireisl-Rocca-Schimperna [10] and Feireisl-Fremond-Rocca- Schimperna [6], where the non-isothermal model with the penalty term $f(d)$ is considered, and those of Lin-Lin-Wang [17], Hong [18], and Hong-Xin [19], where the isothermal model with term $|\nabla d|^2 d$ is considered, we consider the non-isothermal model, that is, systems (1.1)–(1.4) and (1.8)–(1.11), and we are going to prove the global existence of weak solutions."

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Adverbs

Use adverbs to change the meaning of the verb, not to express a meaning already in it.

Original: The algorithm completely failed to provide any correct significant digits in the computed solution.

Better: The algorithm failed to provide any correct significant digits in the computed solution.

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Better: The algorithm failed to provide any correct significant digits in the computed solution.

Original: . . . the realization that higher resolution simulations will inevitably require the replacement of the whole HPC software stack.

Better: . . . the realization that higher resolution simulations will require the replacement of the whole HPC software stack.

Adjectives

Original: The numerical experiments show that the algorithm produces very accurate results.

Better: The numerical experiments show that the algorithm produces results with errors at the level of the unit roundoff.

Minimize use of adjectives and adverbs.
See **Cluttered writing: Adjectives and adverbs in academia** by A. Okulicz-Kozaryn (2013).

Avoid (Double) Negatives

Original: The convergence of (1.1) is not guaranteed without additional assumptions on the function g and the starting vector x_0.

Better: To guarantee convergence of (1.1) assumptions must be made on the function g and the starting vector x_0.

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Original: If the input argument `closure` is set to `true`, all the dependencies are wrapped if they are not explicitly marked as non-exportable.

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Vary Sentence Length

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Example: D. S. Broomhead (PCAM, 2015):

The timetable for a rail network has to coordinate the movements of many independent trains in order to provide a safe and predictable service. A range of issues have to be addressed: railway stations have limited numbers of platforms; parts of the network may have single-track lines; passengers need to make connections; etc. Max-plus algebra provides useful tools to do this.

Name When You Cite

Original: Previous work [4], [9] has shown that. . .

Better: Smith [9] and Jones [4] have shown that . . .

Name When You Cite

Original: Previous work [4], [9] has shown that. . .

Better: Smith [9] and Jones [4] have shown that . . .

Original: . . . as shown in [2].

Better: as shown by Vaughan and Williams [2].

Say What You Mean

Context: a nonlinear eigenvalue problem known to have real eigenvalues.

Original: Our new algorithm guarantees real eigenvalues.

Say What You Mean

Context: a nonlinear eigenvalue problem known to have real eigenvalues.

Original: Our new algorithm guarantees real eigenvalues.

Better: Our new algorithm guarantees real computed eigenvalues in floating point arithmetic.

Revising

- "Begin by cutting out the big stuff. Brevity comes from selection, not compression" (R. P. Clark).
- Editor Maxwell Perkins reduced one four-page passage of Thomas Wolfe's about his uncle to six words:
  'Henry, the oldest, was now thirty'.
- Wait a few hours or days between writing and revising.
- Revise by hand on a printout?

Recommended Reading on Writing

- Roy Peter Clark, **Writing Tools: 55 Essential Strategies For Every Writer**, Little, Brown and Company, 2016.
- Stephen King, **On Writing Well: A Memoir of the Craft**, xv+367, Hodder and Stoughton, 2000
- William Zinsser, **On Writing Well: An Informal Guide to Writing Nonfiction**, xiii+288, HarperCollins, 1990

Exercise

Original: The editors strongly encourage authors to deposit, in a permanent repository or as supplementary materials, any software and data that allow the results of published articles to be reproduced, and every effort should be made to include sufficient information in manuscripts to enable this.

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Better: Authors should include sufficient information in the manuscript to enable the results of the manuscript to be reproduced. To this end, authors should deposit in a permanent repository, or as supplementary materials, relevant software and data.

Exercise

Original: Combining the previous two inequalities together, we obtain . . .

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Better: Combining the previous two inequalities, we obtain ...

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Original: The maximal value grows larger for larger m.

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Better: Combining the previous two inequalities, we obtain ...

Original: The maximal value grows larger for larger m.

Better: The maximal value grows with m.

Outline

Workflow

Tools, techniques for whole research process, esp. typesetting, numerical experiments.

See chapter **Workflow** from **The Princeton Companion to Applied Mathematics**.

The Old Days

Producing maths on typewriters and wordprocessors

$$E(||\underline{x}||_2^2) = \theta^2 \sum_{i=1}^{n} \frac{1}{\sigma_i^2} = \theta^2 ||A^{-1}||_F^2. \qquad (2.2.4)$$

$$\|A + BU\|_F^2 = \sum_{i=1}^{n} (\sigma_i(A)^2 + 2\sigma_i(B^*A) + \sigma_i(B)^2).$$

$$\sum_{k=1}^{N} (m - (k-1)\cdot r)\cdot r \approx mn - n^2/2$$

LaTeX Tips

See my LaTeX Tips document in my GitHub repository
https://github.com/higham/latex-tips

The document also exists in the form of one of my
LaTeX blog posts 

Plain Text is King

- **Maximize** use of plain text.
- **Minimize** use of proprietary formats such as `.doc`, `.docx`, `.xls`, `.xlsx`.
- For writing can use markup languages:
  - **Markdown** (**cheatsheet**).
  - Emacs **Org mode** (**cheatsheet**).
  - LaTeX.

Version Control

- Avoid `paper1.tex`, `paper2.tex`, ...
- Database of different versions of files and changes.
- A form of backup.
- Integration with many editors.
- Recommend **Git**.

Outline

Summarize Results in a Theorem

Be precise and do not overstate your claims.

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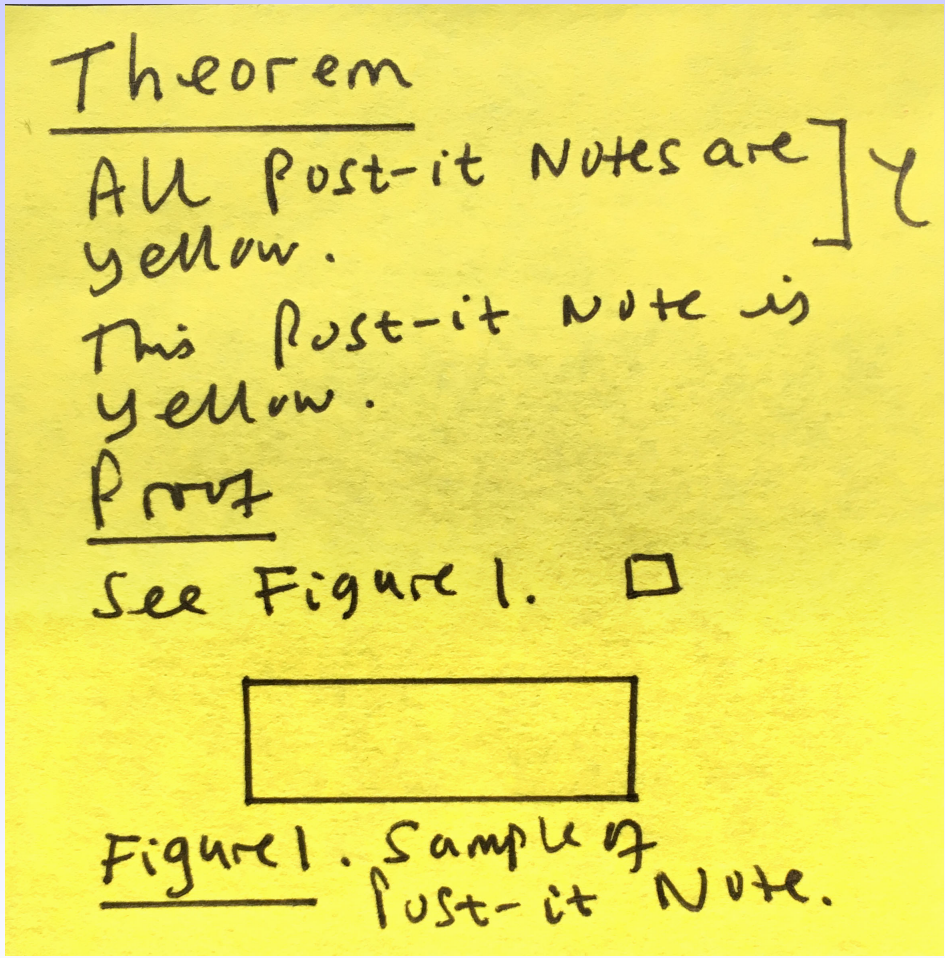

Fine-Tuning a Theorem

Word as simply and clearly as possible.

Theorem

Let $A \in \mathbb{C}^{n\times n}$ have no eigenvalues on $\mathbb{R}^-$. Then

$$\operatorname{acos} A + \operatorname{asin} A = \frac{\pi}{2} I.$$

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Theorem

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Dos and Don'ts (1)

Bad:

$$x^2 + bx - c = 0$$
$$(x + b/2)^2 = c + b^2/4$$
$$x + b/2 = \sqrt{c + b^2/4}$$
$$x = -b/2 + \sqrt{c + b^2/4}.$$

Much better: We have

$$0 = x^2 + bx - c = (x + b/2)^2 - c - b^2/4.$$

Rearranging and taking the positive square root gives

$$x = -b/2 + \sqrt{c + b^2/4}.$$

Dos and Don'ts (2)

Watch for notational synonyms.

Original: If $\lambda_i \neq \lambda_j$ for all $i \neq j$ ...
Alternative: If the eigenvalues are distinct ...

Original:

$$A = X \begin{bmatrix} \lambda_1 & & & \\ & \lambda_2 & & \\ & & \ddots & \\ & & & \lambda_n \end{bmatrix} X^{-1}$$

Alternative: $A = X\mathrm{diag}(\lambda_i)X^{-1}$.

Dos and Don'ts (3)

- Punctuate all equations (as in the handouts). E.g.

  We consider the initial value problem

  $$y'(t) = 2y(t), \qquad y(0) = 1,$$

  over the range $0 \le t \le 1$.

- Don't start a sentence with a symbol.
  Bad: A is an ill-conditioned matrix.
  Good: The matrix A is ill-conditioned.
- Separate symbols by punctuation marks or words.
  Bad: If $x = 1$ $f(x) = 0$.
  Fair: If $x = 1$, $f(x) = 0$.
  Good: If $x = 1$ then $f(x) = 0$.

Dos and Don'ts (4)

Don't put "big" equations in-line.

Bad: We find that $f(x) = \frac{1}{1-x} - \frac{1}{1+x}$.
Good: We find that $f(x) = 1/(1-x) - 1/(1+x)$.
Good: We find that

$$f(x) = \frac{1}{1-x} - \frac{1}{1+x}.$$

Example

From a textbook on linear algebra:

Define a square matrix E_{ij} by

$$[E_{i,j}]_{kl} = \begin{cases} 0, & k \neq i,\ k \neq j,\ l \neq k, \\ 1, & k \neq i,\ k \neq j,\ l = k, \\ 0, & k = i,\ l \neq j, \\ 1, & k = i,\ l = j, \\ 0, & k = j,\ l \neq i, \\ 1, & k = j,\ l = i. \end{cases}$$

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Better:

Let $E_{i,j}$ be the matrix obtained by swapping the ith and jth rows of the identity matrix.

Study Other Writers

Learn by studying the work of writers you admire.

- What makes their papers stand out?
- What vocabulary do they use?
- How do they weave together text and mathematics?
- How do they tell the story?
- What stops their writing from being boring?

Outline

Commonly Confused Words (1)

- **alternative**, **alternate**
- **affect** (verb), **effect** (noun)
- **compare with** (similarities, differences), **compare to** (use only in poetry and love letters)
- **comprise** (to consist of), **compose** (to make up), **constitute**: The exam comprises 7 questions, the course is composed of 3 topics, these 3 topics constitute the course.

Commonly Confused Words (2)

- **fewer** (use w/plural nouns), **less** (use w/singular nouns): fewer iterations, less computation
- **practice** (noun), **practise** (verb)
- **which** (informs and does not restrict), **that** (defines and restricts):
  - Consider the Hilbert matrix that is positive definite.
  - Consider the Hilbert matrix, which is positive definite.

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Use a dictionary! Other examples: **annex–annexe**, **especially–specially**, **licence–license**.


TEN ITEMS
OR LESS
TEN ITEMS
OR FEWER
FOR
PEDANTS

Distinctions

- **phenomenon** (singular), **phenomena** (plural)
- **criterion** (singular), **criteria** (plural)
- **discrete** (distinct, not continuous), **discreet** (unobtrusive).

Watch Out for These Mistakes

- supersede (incorrect: supercede)
- loose instead of lose
- MATLAB (incorrect: Matlab).
  Do not write “MATLAB’s `expm` function”.
- **its** is a possessive (“its solution”),
  it’s is a contraction of **it is** (“it’s clear that”).

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1. INTRODUCTION. In 1966 Kac [7] asked the question "Can you hear the shape of a drum?", that is, if you know the frequencies at which a drum vibrates, can you determine it's shape? Mathematically this corresponds to the following problem. If u is the displacement of a membrane D from its mean position, then u satisfies

For Non-Native Writers

- If in doubt, include the article **a** or **the**.
- Read good expository technical English writing, e.g. SIAM News, Scientific American.
- Identify writers whose papers you find enjoyable to read and make notes of their phrases, vocabulary, etc.

Take a look at this book, available here.

Leonardo da Vinci programme
European Commission

Writing in English

A Practical Handbook for Scientific and Technical Writers

A Pilot Project

Project Partners

Zuzana Svobodova, Technical University Brno, Czech Republic
Heidrun Katzorke and **Ursula Jaekel,** Technische Universität, Chemnitz, Germany
Stefania Dugovicova and **Mike Scoggin,** Comenius University, Bratislava, Slovakia
Peter Treacher, ELT Centre, University of Essex, England

Dangling Participle

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- A bug was found in the program using random test data.
- Hastily summoning an ambulance, the corpse was carried to the mortuary.

Bastard Enumeration

The Basic Linear Algebra Subprograms (BLAS) have several advantages. They

- Lead to shorter and clearer codes;
- Improve modularity.
- Machine dependent optimizations can be confined to the BLAS, aiding portability, and
- Tuned BLAS have been provided by manufacturers.

Entries should be grammatically parallel.

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Variation:

There are three reasons.
(a) . . .
(b) . . .
And thirdly . . .

Active versus Passive

Active: X did Y.
Passive: Y was done by X.

- Active voice is more lively and often more concise.
- Passive voice is more vague and indirect.

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Passive: Estimation of the error was achieved by application of the Peano kernel formula.

Active: We estimated the error using the Peano kernel formula.

Active versus Passive

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- Active voice is more lively and often more concise.
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Passive: Estimation of the error was achieved by application of the Peano kernel formula.

Active: We estimated the error using the Peano kernel formula.

Passive: The specimen was accidentally strained during mounting.

Active: I dropped the specimen on the floor.

Naked This

Consider the sentence

> *This raises the question of whether the method always converges.*

"This" could refer to

- most recent noun in previous sentence,
- subject of previous sentence,
- idea of previous sentence,
- something else.

Qualify "this" with the appropriate noun: "this result", "this argument", . . . to avoid ambiguity.

Even better: **rewrite** to avoid the overused "this" completely.

Lively Writing (1)

Try *not* to begin a sentence with

- It is . . .
- It can be . . .
- There is . . .
- There are . . .
- Also . . .

Never use the word “thing”—be more specific.

Lively Writing (2)

Bad: It can be seen in Table 4 that the residual is monotonically decreasing.

Good: Table 4 shows that the residual decreases monotonically.

Lively Writing (2)

Bad: It can be seen in Table 4 that the residual is monotonically decreasing.

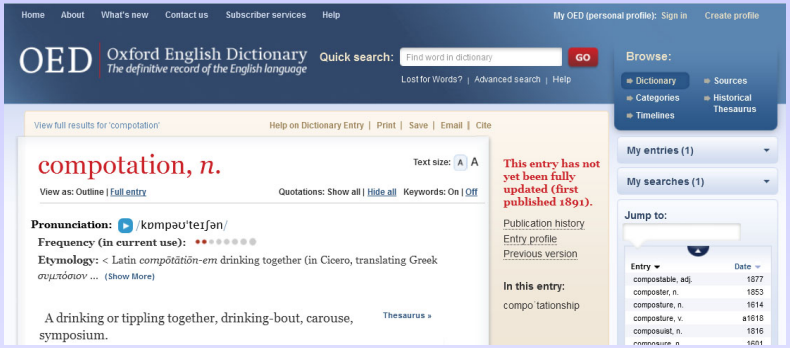
Good: Table 4 shows that the residual decreases monotonically.

Bad: There are several possibilities that can be used to break ties.

Good: Ties can be broken in several ways.

Online Resources

- **Oxford English Dictionary**



- **The King's English**, H. W. Fowler and F. G. Fowler, Second edition, 1908.
- **The Elements of Style**, William Strunk, Jr., 1918.

Style Guides

- Journals of the London Mathematical Society: **house style and instructions for copy-editors and typesetters**
- **SIAM Style Guide**
- **Wikipedia:Manual of Style/Mathematics**
- **IEEE Editorial Style Manual**
- **The Chicago Manual of Style** (subscription required)
- **The Best Style Guides** (web article)

Exercise

Original: We are neither hoping to reconstruct the data in its full entity nor to achieve the high quality compression of specialized methods.

Exercise

Original: We are neither hoping to reconstruct the data in its full entity nor to achieve the high quality compression of specialized methods.

Better: We are neither hoping to reconstruct the data in its **entirety** nor **aiming** to achieve the high quality compression of specialized methods.

Outline

The Title

The title should

- Give a terse description of the content.
- Be catchy.

J. L. Kelley:

Before: *A decomposition of compact continua and related results on fixed sets under continuous mappings*

After: *Simple links and fixed sets*

Some Good Titles

How and how not to check Gaussian quadrature formulae

ALGOL 68 with fewer tears

Nineteen dubious ways to compute the exponential of a matrix

Iterative refinement implies numerical stability for Gaussian elimination

Can you count on your calculator?

Structured polynomial eigenvalue problems: Good vibrations from good linearizations

No So Good Titles

Perturbation bounds for the nonsymmetric eigenvalue problem

A BIE method for a nonlinear BVP

A Report on Harmonic Maps (1978)
Another Report on Harmonic Maps (1988)

Outline

Basics

- Give enough detail to enable *interpretation* and *repetition* of experiment. State, e.g.,
  - Machine precision.
  - Compiler & options, optimizations; BLAS library.
  - Type of random numbers.
- State only as many digits as needed.
- Be wary of extrapolating from results.
- Distinguish between objective statements and speculation.

Reproducible Research

Wikipedia

http://en.wikipedia.org/wiki/Reproducibility

- "**Reproducibility** . . . refers to the ability of an entire experiment or study to be reproduced, or by someone else working independently."
- "The term **reproducible research** was first proposed by Jon Claerbout at Stanford University and refers to the idea that the ultimate product of research is the paper along with the full computational environment used to produce the results in the paper such as the code, data, etc. necessary for reproduction of the results and building upon the research."

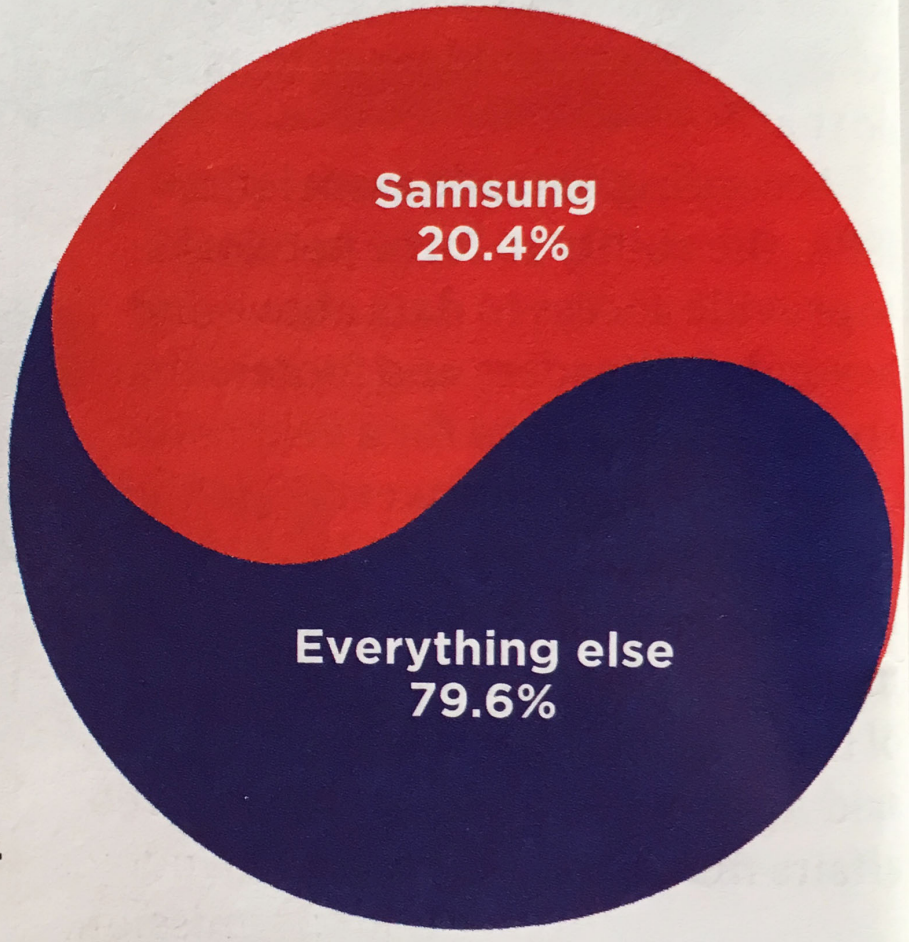
Table or Graph?

- Table better for small sets of numbers.
- Graph better for large data sets & to show trends.
- Tables:
  - Keep simple.
  - Minimum number of rules.
  - Like quantities to be compared better in columns than rows.
- Graphs:
  - Ensure readable.
  - Iterate on design.

See **Ten Simple Rules for Better Figures** (2014).

Korean power

No other technology company dominates a country's economy quite like Samsung, which contributed a vast 20.4% of South Korea's GDP in 2014. Visit the country and you see Samsung signs everywhere.



South Korea GDP 2014

MATLAB

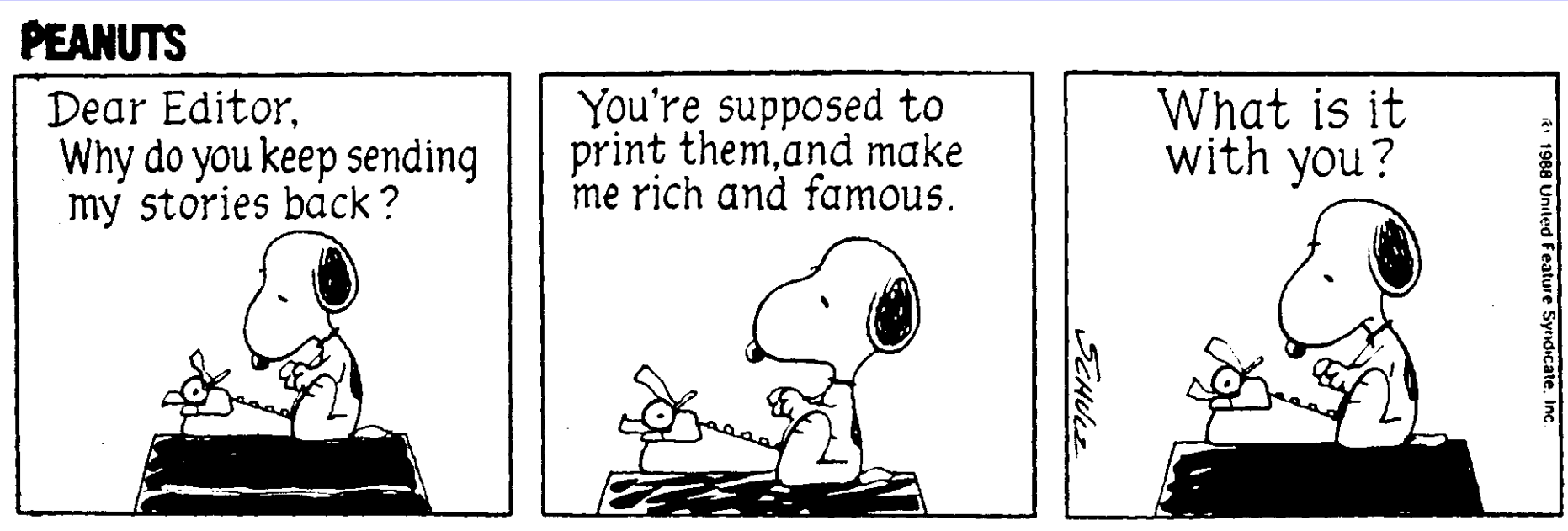
- Use `typewriter font` for MATLAB code, function names, variables, and output.

  Wrong: Before invoking int we first set up symbolic variables x and f.
  Right: Before invoking `int` we first set up symbolic variables `x` and `f`.

- Make MATLAB M-files and output clearly distinct from surrounding narrative, perhaps by using smaller font size and narrower margins.

- You should not materially change MATLAB output, but you can remove blank lines and "tidy up" output.

Outline


PEANUTS
Dear Editor,
Why do you keep sending my stories back?
You're supposed to print them, and make me rich and famous.
What is it with you?
SCHULZ
© 1988 United Feature Syndicate, Inc.

Proofreading Test (1)

- One of the best unknown methods for determining all the eigenvalues and eigenvectors of (2.1) was developed by the nineteenth century mathematician Jacobi.

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- It would be hard to underestimate the importance of optimization to scientific computing.

Proofreading Test (2)

- **Acknowledgements**. I thank the anonymous referees, particularly Dr. J. R. Ockendon, for numerous suggestions and for the source of references.

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- All these approaches lead to nontrivial loss of accuracy when larger CNN models were trained for ILSVRC classification tasks (Zhou et al. (2016)).

Proofreading Test (3)

the balanced oscillator gain function defined by

$$k(z) \equiv \frac{2}{z} \int_0^1 \tanh(9z)\sin(2\pi t)\sin(2\pi t)\,dt \tag{17.2}$$

is not a canonical special function either, but Boyd and Visser have derived power se-

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Should be

$$k(z) \equiv \frac{2}{z} \int_0^1 \tanh\bigl(z\sin(2\pi t)\bigr)\sin(2\pi t)\,dt.$$

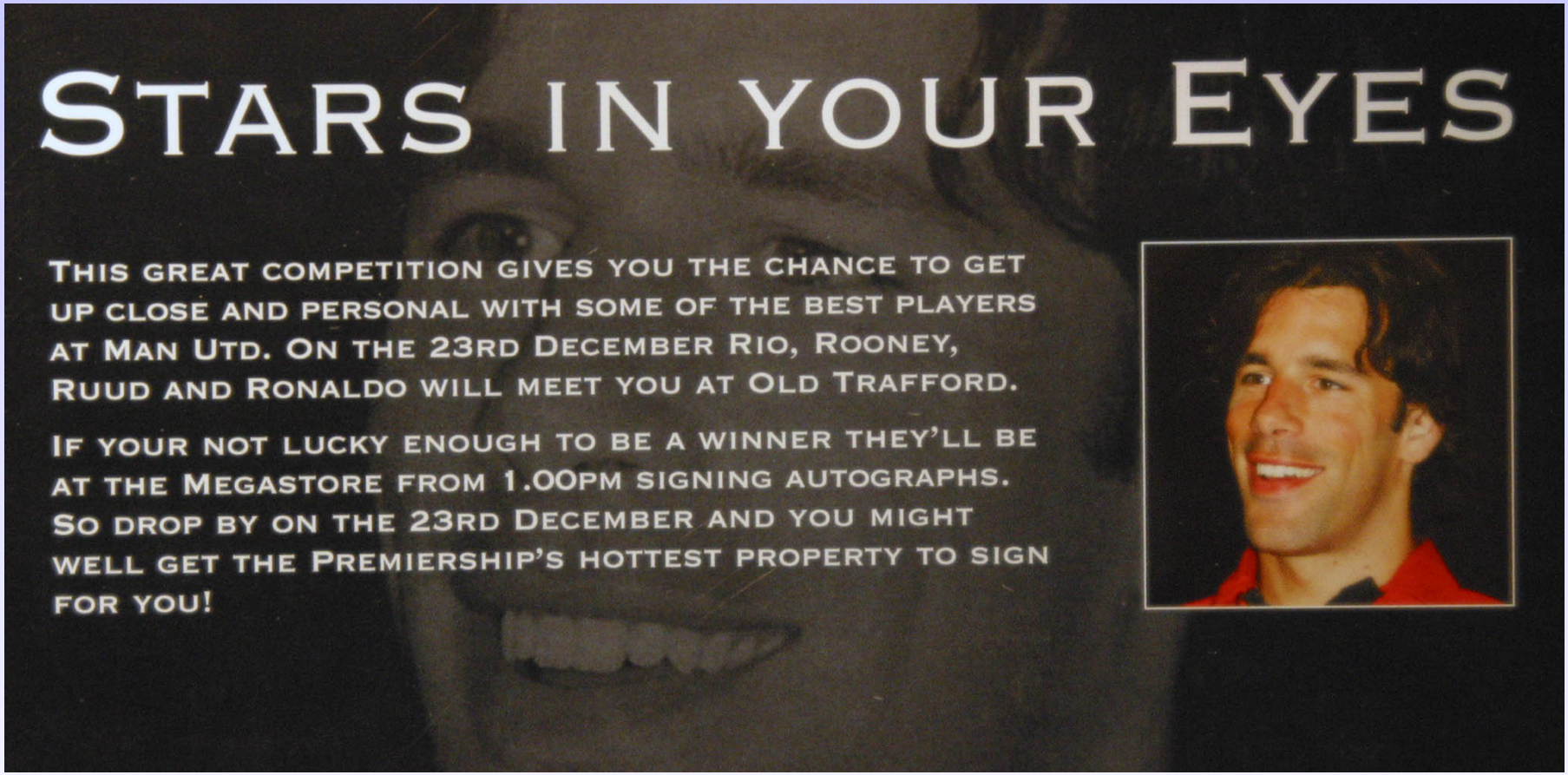
Proofreading Test (4)

WITH chancellor George Osborne pinning his hopes on private investment in infrastructure, the call from the West Midlands transport authority to nationalise the M6 toll road, overpriced and merely forcing traffic on to the congested main M6, could hardly have come at a worse time.

The toll road, completed under the private finance initiative ten years ago, epitomises most of what is wrong with PFI. The high tolls that render it a failure are demanded by sky-high interest payments that the operator, Midland Expressway Ltd, pays at rates up to 12 percent. Through a series of holding companies, these end up with a parent company in Bermuda that is managed by the Australian Macquarie group.

Levied on borrowings of more than £700m, the interest wipes out all taxable profits so, contrary to the assumptions made when PFI contracts are agreed, this one makes no corporate tax contribution at all. It's not so much the "Birmingham Northern relief road" promised as a tax relief road to Bermuda.

Spot the Error



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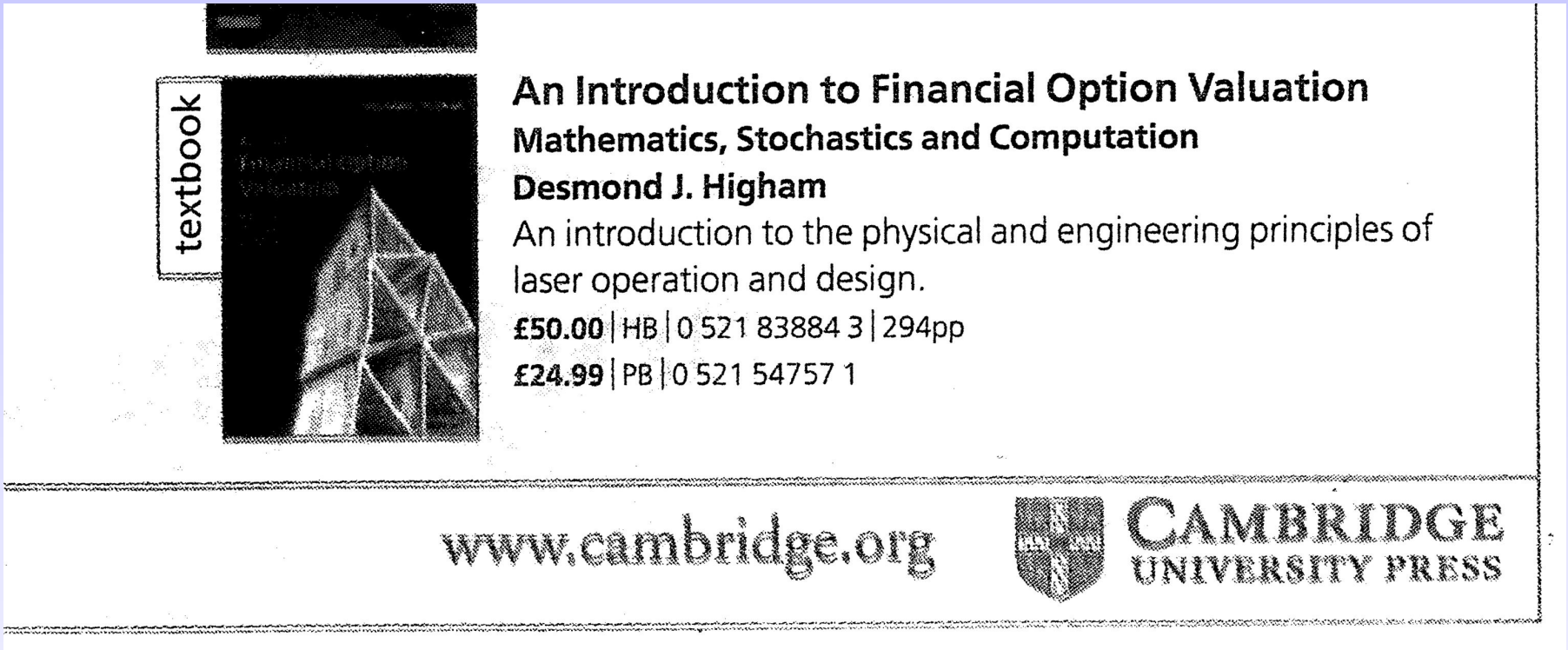

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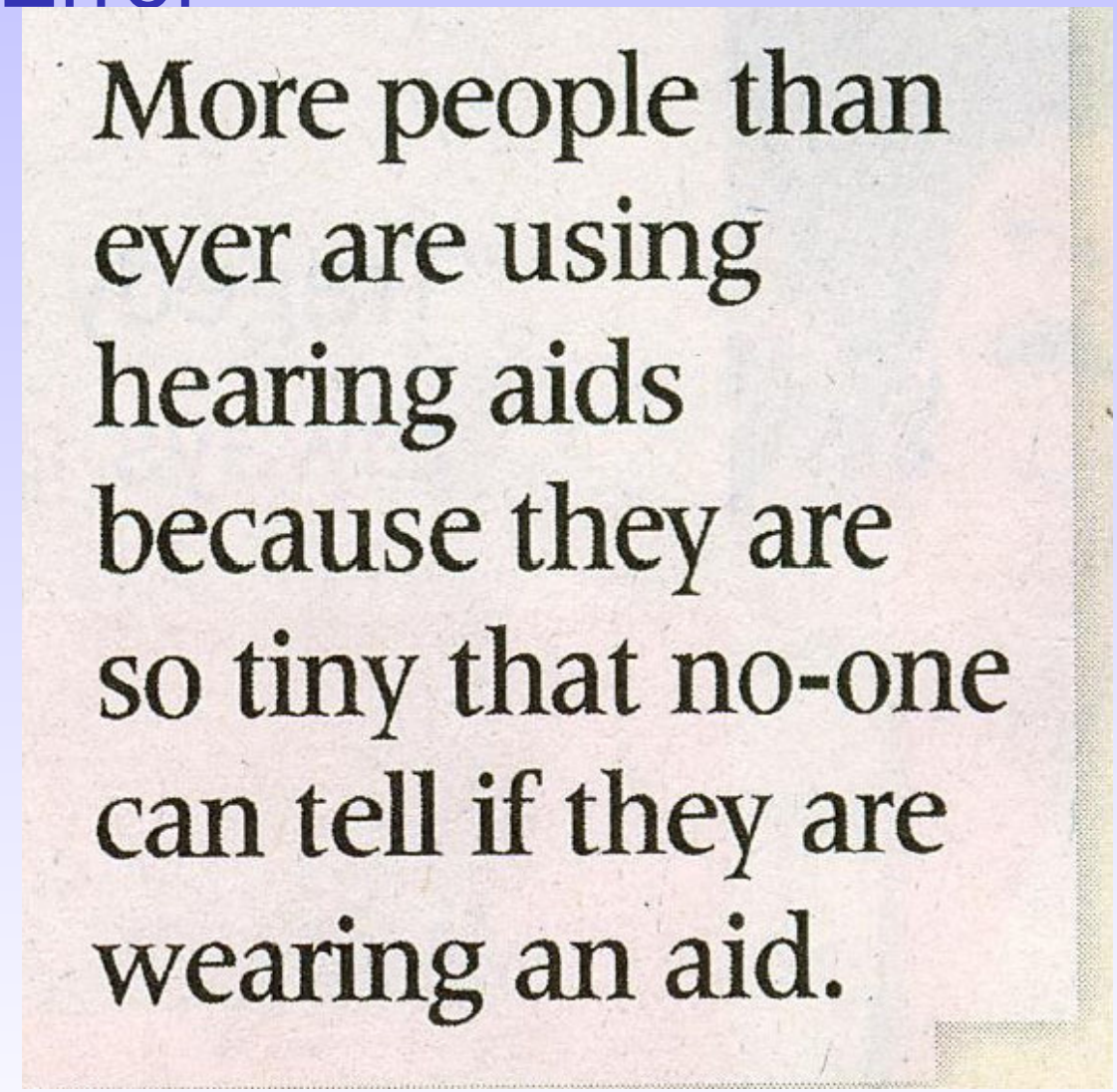
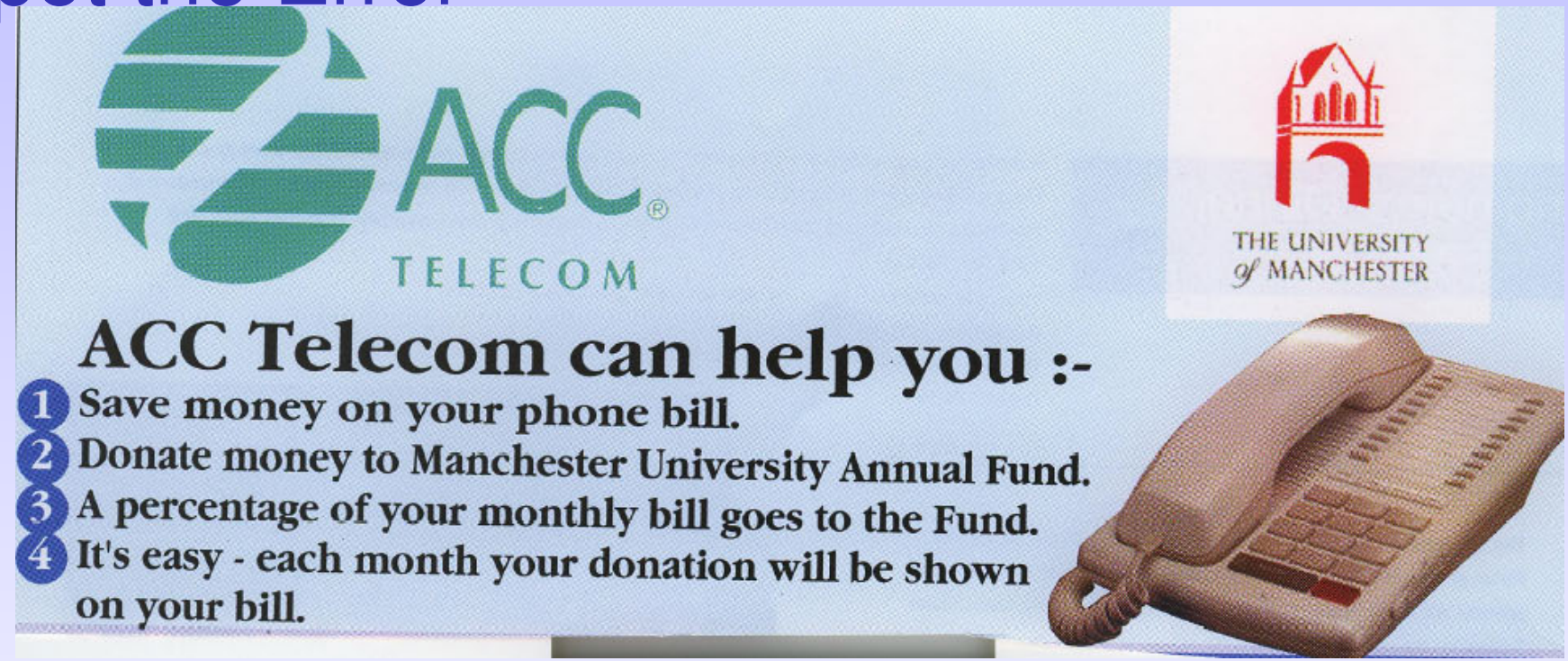


Spot the Error

Repeat flowering

Most poinsettias end up on the compost heap when they loose their colour, but it is possible to keep them for the following year,

Spot the Error



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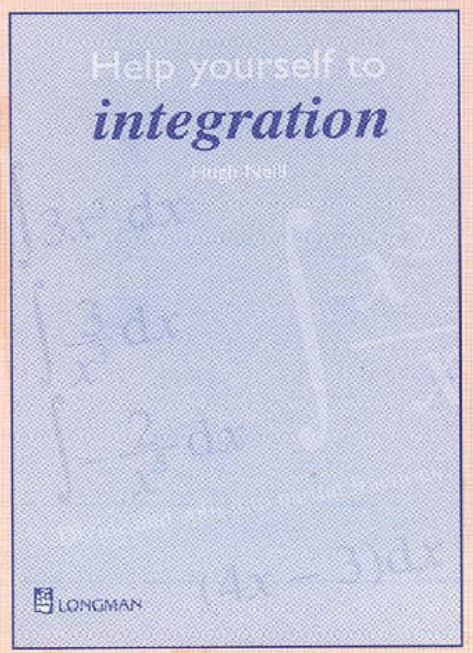

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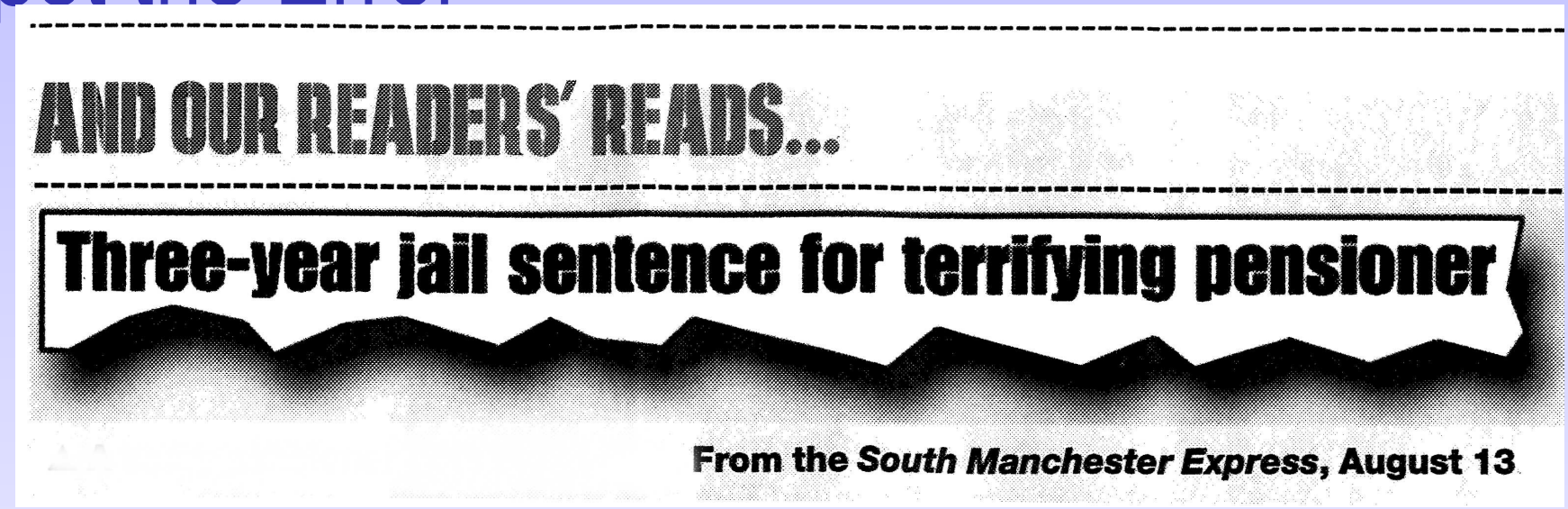

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SUPERBABY: Scott James Howarth-Petruzis
Picture: Eddie Garvey

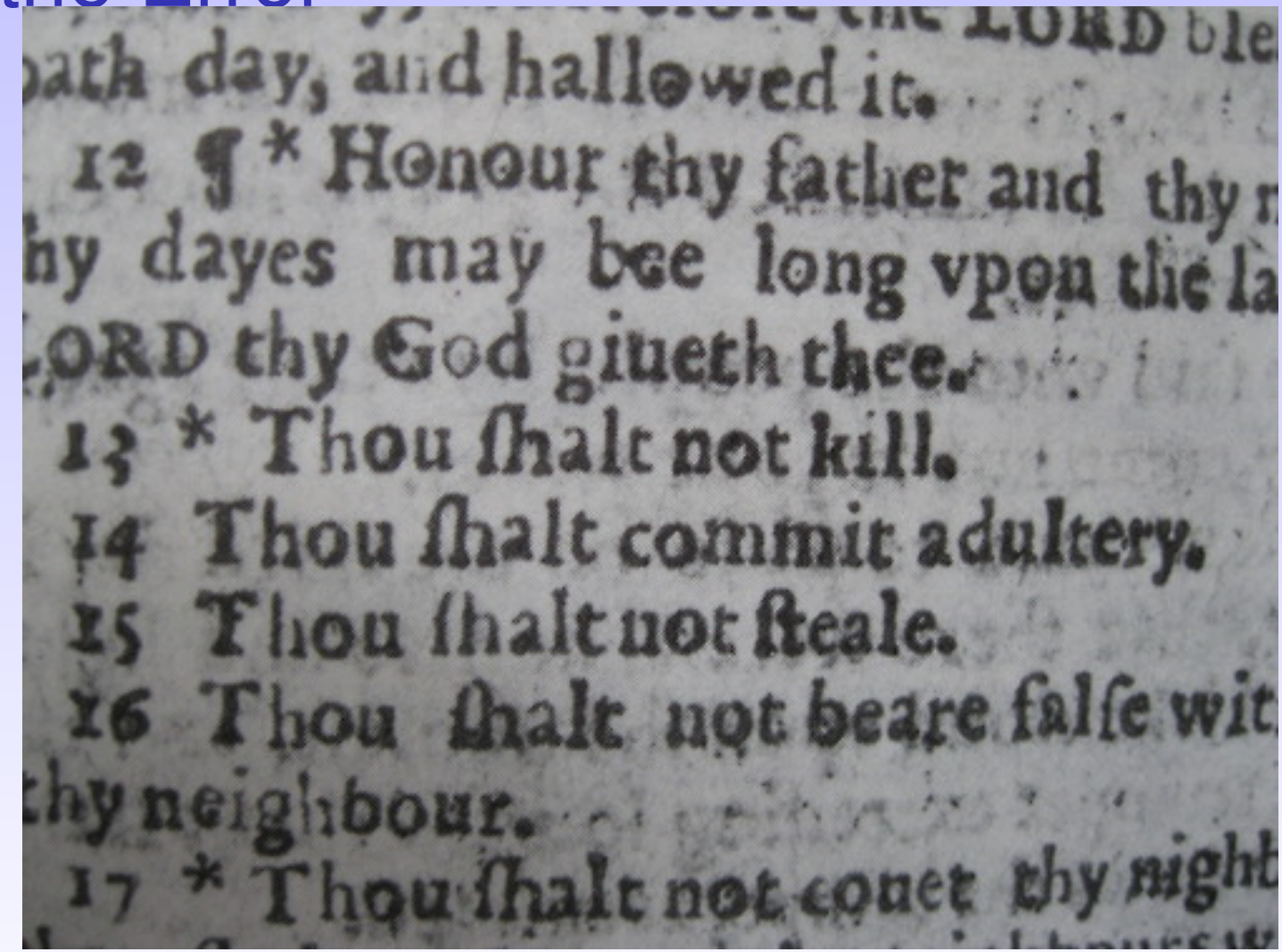
SUPERBABY FLYS OFF TO DISNEY

BY PAMELA WELSH

THE parents of a seriously ill boy have called their son a 'superbaby' after he came through a life-threatening illness.

Trip of a lifetime for plucky nipper

Spot the Error



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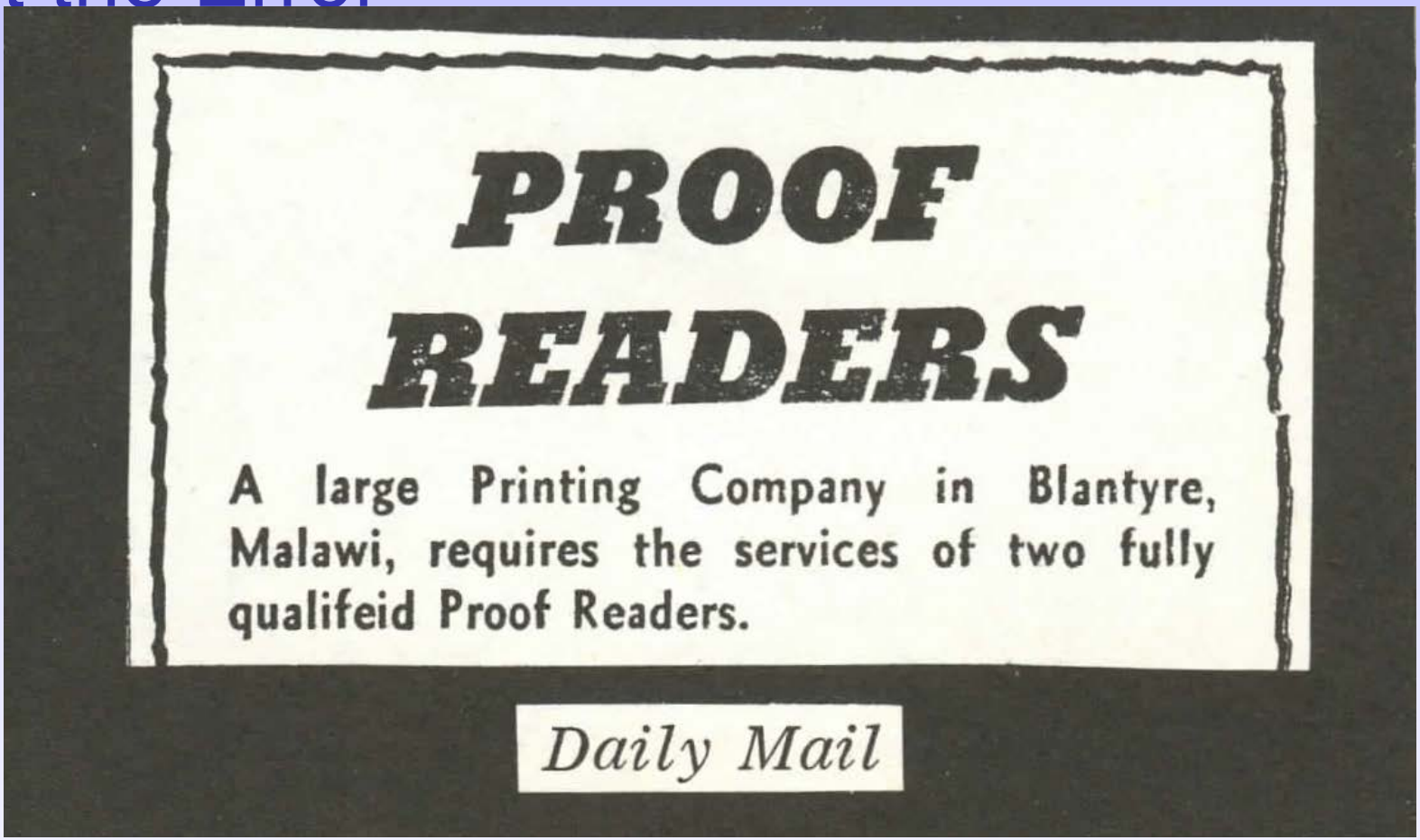
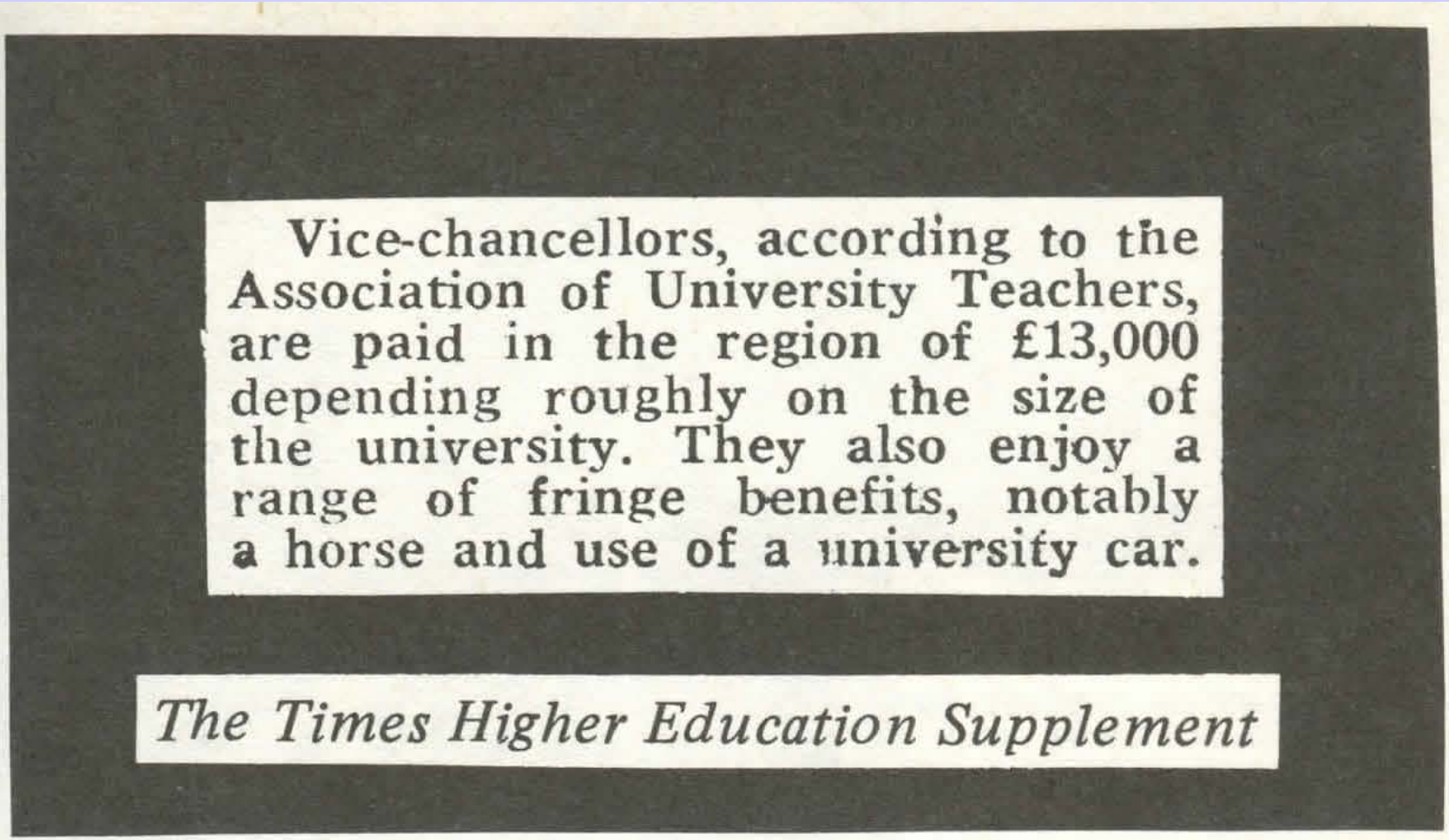


Spot the Error

Whether he's photographing a couple on a Love Journey shoot, a wedding day or approaching interesting looking characters on the street, Jimmy favours a discrete approach. Which is why his Canon cameras have given way to Olympus OM-Ds. "Canon brought

Spot the Error



Vice-chancellors, according to the Association of University Teachers, are paid in the region of £13,000 depending roughly on the size of the university. They also enjoy a range of fringe benefits, notably a horse and use of a university car.

The Times Higher Education Supplement

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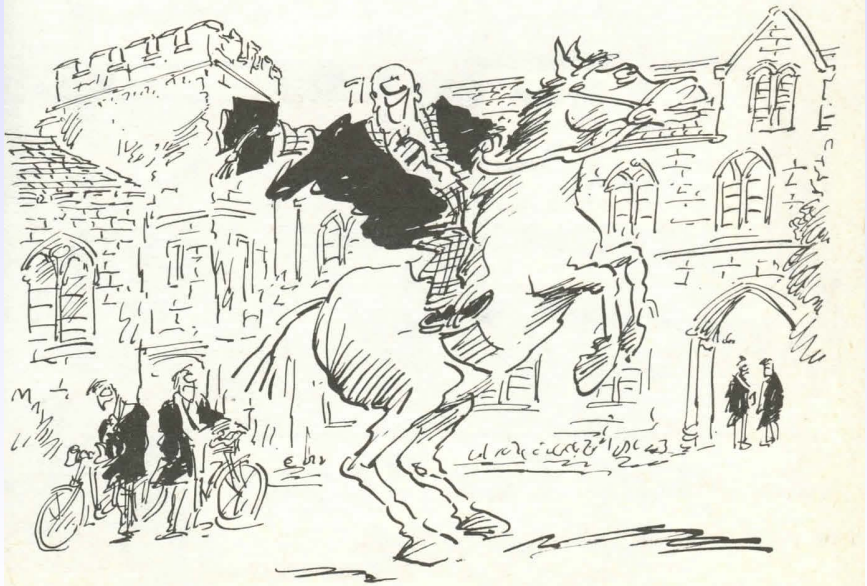
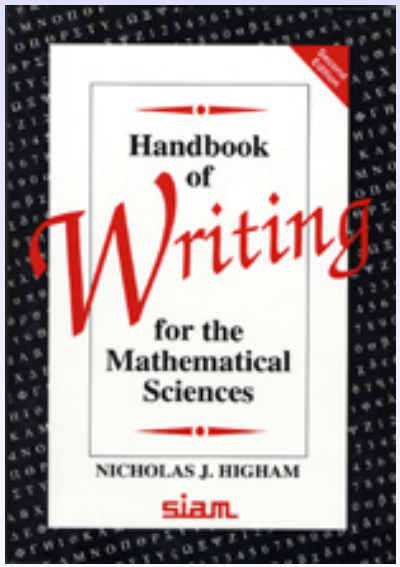


For more information about any of the topics discussed here see

Nicholas J. Higham, Handbook of Writing for the Mathematical Sciences, Second edition, SIAM, Philadelphia, 1998

and the links at

http://www.maths.manchester.ac.uk/~higham/hwms



References I

Roy Peter Clark.
Writing Tools: 55 Essential Strategies For Every Writer.
Little, Brown and Company, New York, 2016.
10th Anniversary Edition.
ISBN 978-0-316-01499-1.

George Grätzer.
More Math Into LaTeX.
Fourth edition, Springer-Verlag, New York, 2007.
ISBN 978-0-387-32289-6.

References II


Nicholas J. Higham.
Handbook of Writing for the Mathematical Sciences.
Second edition, Society for Industrial and Applied Mathematics, Philadelphia, PA, USA, 1998.
xvi+302 pp.
ISBN 978-0-898714-20-3.


Donald E. Knuth, Tracy Larrabee, and Paul M. Roberts.
Mathematical Writing.
MAA Notes Number 14. Mathematical Association of America, Washington, D.C., 1989.
115 pp.
Also Report STAN-CS-88-1193, Department of Computer Science, Stanford University, January 1988.

References III

ISBN 0-88385-063-X.

Steven G. Krantz.
A Primer of Mathematical Writing: Being a Disquisition on Having Your Ideas Recorded, Typeset, Published, Read, and Appreciated.
American Mathematical Society, Providence, RI, USA, 1997.
xv+223 pp.
ISBN 0-8218-0635-1.