Bottom line: If you need to refer to an item more than once, it is best to give it a name. If you need to refer to two or more similar things (two numbers, three graphs), give them each a name. If you will do computations (algebra) with your names, make each a single symbol (or a symbol with a subscript or superscript). If you won’t need computations, multisymbol names are OK and may be easier to remember. See §8.5 for more on how to introduce notation.

Continuing with the graph theory example, if intended readers have learned a bit more graph theory notation (for instance, $E(G)$ for the edge set of $G$), then you can be more succinct:

We find a cycle $C$ in our graph $G$. If $E(C) = E(G)$, we are done. Otherwise, find a cycle $C'$ in $G' = G - C$. If $E(C') \neq E(G')$, then...

But just as the first version used too little symbolism, this third version may use too much, especially if your readers are new to the additional notation.

**Section 22. Writing Tools: Computers and Hands**

Should you write your mathematics by hand or on a computer? The answer is no doubt “both”, but the proportions depend on your interests and purposes.

Most students today write their longer papers in nonmathematical subjects with word processors. For mathematics the issue is complicated, because general word processors are not particularly good at producing mathematics; their mathematical formatting is crude and slow. Special mathematics writing software, notably \TeX{} and its extensions, can format even the most complicated mathematics beautifully, but this software takes a long time to learn to use well, and takes time to use even then. The matter is further complicated because formatting mathematics for web documents involves even more levels of complication.

**Advice:** If you foresee writing just one or two math papers, then use whatever general software you already know, and fill in complicated expressions by hand; or do the whole paper by hand. On the other hand, if you might go to graduate school in a mathematical subject, or have a career involving mathematics, or even if you are involved in a single mathematical paper that might be published, then it is worth it to begin to learn \TeX{}. The reasons for this conclusion are explained in §9.22.B.

The organization of the rest of this section is as follows. The first subsection discusses the general pros and cons of using a computer in writing. The next subsection explains the differences for mathematics between general and special wordprocessors. The final two sections advise you how to handle mathematical expressions and figures, the two things for which handwriting, general processors, and mathematical processors are most different.

Anything with computers is a moving target. Before long you will be able to put something shaped like a pad of paper on your desk, write on it freehand with something like a pencil, and
have it be recorded on your computer and editable. Eventually, software may be able to translate your freehand into code so that it can be rendered in traditional symbols and published either on hardcopy or as web documents. Things will be a lot easier at that point – except that no doubt we will all then try to do fancier things.

A. General Pros and Cons of Writing with Computers

Pros. First, assuming you can type much faster than you write, you will get your thoughts recorded much faster on a computer – you’ll actually get some sentences finished whereas with handwriting you’ll slow down and cross out and may get discouraged before you get any sentence finished. Thus, for fast typists, typing instead of handwriting can help you start, and help you progress faster.

Second, revising is so much easier on a computer. You can do some immediate editing even as you write your first draft – you can delete bad phrases and misspellings right away and so you will have a much cleaner copy when you sit down to do major revisions. And because revision is easier, you are likely to do much more of it, resulting in a better paper than if you wrote by hand. (See §6.4 for the pros and cons of making those major revisions on the computer.)

Third, computers make it very easy to file and retrieve information – if you use a naming scheme you can remember and make good use of the tools available (e.g., folders within folders, and find-commands for finding file names and items within files). See §3.3.A.

Fourth, computer output looks so much nicer than handwriting and is so much easier for everyone to read.

Cons. Precisely because it is easier for many people to keyboard instead of handwrite, the computer can lull you into false complacency. You just sit down and start typing your paper, and maybe even get a lot written, before you have thought enough about what you are writing. You ought to be doing some planning and outlining first.

Second, with a computer it’s easy to get caught up on peripheral issues. Computers, and especially laser printers, can make papers look very good. But there are two problems with these good looks. First, you can dally endlessly with the looks. Second, good looks doth not a good paper make. While the looks of a math paper make a difference (see §9.13), looks are not something to spend a lot of time on when starting on a paper, or at any point if mathematics is not a central subject for you.

Third, typing mathematics on a computer is tedious. You don’t want to get hung on this issue when you when you should be thinking about content.

Fourth, you can’t think hard while typing. It’s almost impossible, say, to compose the proof
of a subtle theorem at the keyboard, but you might be tempted to try. If you are typing a subtle argument, or the notation is complicated, you need to write out a hand copy anyway before putting it on the computer.

Fifth, things can go wrong with computers that can’t go wrong with paper and pencil. The disk could crash. A frill you thought was going to be easy to implement (say, formatting a table a certain way) may turn out to be just beyond your reach, and you may end up spending hours on it that you don’t have. Good advice: never try something new with computers on an assignment that is due soon.

Sixth, overuse of computers or improper use (in the sense of how you sit, or hold your hands, or how long you stare at the screen before taking a break) sometimes lead to certain health problems, such as repetitive strain injuries. Most computer manuals give some advice on these matters, and there are whole books and websites on the issue.

Many of these cons are not reasons to avoid computers entirely, but only to avoid them until your paper is well along, or to use a mixture of handcopy and computer. With practice, you will develop a mixture that works best for you.

B. General and Mathematical Word Processors

There are two ways currently to get the full gamut of mathematical symbolism into computer-written papers:

- Use an equation editor, which is a type of plug-in to certain full-featured general word processors;
- Use special mathematics writing software (also called mathematics typesetting software or mathematics compositing software), of which the preeminent one is \( \text{TeX} \) and its various extensions, notably \( \text{LaTeX} \).

Equation editors. Equations editors are easy to learn for mathematical expressions of easy to middling complexity, and an hour or two will take you a long way towards handling complicated math with them (such as multiline displays with several fonts, unusual symbols, and numbering of some of the lines). They work like the word processors they plug into; you pull down a menu to select them, and then you pull down menus within them to build your mathematical expression. They create the mathematical expression as a graphic that sits in your file.

For instance, if you want to create \( \sum_{i=1}^{n} x_i \), you would first select \( \sum \) from a menu, and then the program will step you through the bottom (where you type in \( i = 1 \)), the top (you type \( n \)), and the summand (you type \( x_i \), from a template for subscripted expressions in another menu). The program takes care of making things italic for you, and doing the right spacing.

Furthermore, the program is WYSIWYG – What You See Is What You Get. So if you are not
getting what you want, you realize it right away and try again.

Aside: Equation editors should really be called mathematics editors, or mathematical expression editors. But just as students often think that everything in mathematics is an equation, so do some of the people who write software!

**\text{T\TeX}**. This program isn’t a word processor; rather it is a “text formatter”. You write source code using some other, simple word processor, and in it you embed math formatting commands. Then you run your file through the \text{T\TeX} program, and out comes a second file that can be viewed on the screen or printed out as nicely formatted mathematics. So, for instance, to get $\sum_{i=1}^{n} x_i$ to appear, you create a file containing the symbol string \$\sum_{i=1}^{n} x_i\$$. Say you call the file yourfile.tex. Then you run it through \text{T\TeX}, which produces the file yourfile.dvi. Then you use “drivers” that come along with \text{T\TeX} to view yourfile.dvi on the screen, or print it.

This seems so much more complicated. Why bother? The first reason is portability. Because the source file has no special characters in it (technically, because it is an “ascii” file), it can be sent to others by even the simplest email system and can be read on any computer. The dvi file is also portable; it is a standard “binary” file, and anyone who has \text{T\TeX} software can view it and print it. (In fact, “dvi" stands for “device independent".) There are \text{T\TeX} implementations for PCs, Macs, Unix office computers, and all major mainframe systems.

The second reason is flexibility. You may be happy to print your paper out on an ink-jet printer at moderate resolution, but if your paper is later to become part of a published work, it will be printed at a much finer resolution (more dpi – dots per inch), in a different format, and from a different computer using a different operating system. While some things on a word-processor document can be changed easily (e.g., the margins, or the type size), almost everything about the format of a \text{T\TeX} file can be changed after your write it, by changing the style files that go with it. Another way to express this advantage is to put it as a disadvantage for equation editors: What You See is All You Get.

Third, \text{T\TeX} is in almost universal use among mathematicians and computer scientists (It was invented, almost singly-handedly, by the famous mathematical computer scientist Donald Knuth.) If you plan to work with mathematicians at some point, you will need to know it.

Because of \text{T\TeX}’s wide use, many enhancements have been made to it. The most important enhancement is \text{LaT\TeX}. Not only does \text{LaT\TeX} format mathematics, but it keeps track of equation numbering, section numbering, citations, cross references, etc., and updates them if you change things around. It also comes with many prefabricated formats (“Plain” \text{T\TeX} does not). For instance, if you are willing to accept the format of the “article” style file, you can forget about page formatting and concentrate on the mathematics and the mathematics formatting. (Plain \text{T\TeX} can be made to
do everything \LaTeX does, but you would have to write many complicated commands yourself.)

There is still a lot of work to learning and using \TeX or \LaTeX. You have to go back and forth between source code and output to make corrections. You have to learn a lot of special commands. You have to learn how \TeX is set up at your institution. There are freeware, shareware, and commercial implementations (for PCs, Macintoshes, and Unix machines), with the cheaper versions usually somewhat less user-friendly to install and use. Students may have to use less friendly versions. The friendliest versions are menu driven and are almost WYSIWYG.

Fortunately, because \TeX use is so widespread in mathematics, lots of help is available for you. There are a number of excellent getting-started manuals. Get a more advanced student or an instructor to show you how to get started, then sit down with a manual and try some things. When you get error messages, ask that other student rather than paging through the manual. Use a standard format and don’t try to do anything fancy the first time around. A student of mine, for his first \TeX effort, wrote a 10-page paper full of summations, and he got it to work with only a few extra hours beyond what he would take to write it by hand.

If you have never used \TeX, I recommend that you start by learning \LaTeX. But don’t try to learn something about \TeX first, because \LaTeX is incompatible with some key commands in Plain \TeX (deliberately, but unfortunately). If eventually you become a \TeXpert, and you really care about fine points of formatting, at that stage create your own \LaTeX style files, or program in Plain \TeX instead. But warning: this will be a time-sink. I know!

Web mathematical languages. \TeX is not perfect for electronic documents, because it does not have hyperlinking built in (it was created too early) and it sets things like print width that should not be set for Web documents (the receiving machine sets these). However, translators are already written from \TeX to HTML, and additional translators are under construction from \TeX to MathML (see p. 75). More precisely, translators will be available for \LaTeX, another reason to learn this flavor of \TeX. So it may be that you won’t have to learn yet another mathematical formatter for the Web, although only time will tell.

C. Writing Mathematical Symbols and Expressions

By hand. It’s easy to draw any special symbols. But as for the same symbol in different fonts, don’t try. Unless you are an expert calligrapher, you will not be able to draw consistently even two styles of letters. Depend upon accents and subscript to make all the distinctions you need. If you need $x$ and $\bar{x}$, use $x$ and $\bar{x}$. Instead of $\mathbb{M}$, $\mathcal{M}$, $\mathbf{M}$, and $\mathfrak{M}$, use $M_1, \ldots, M_4$. Well, you can probably make distinguishable roman and script capital M’s, but don’t try to make $\mathbf{M}$ and $\mathfrak{M}$.

As for expressions, by hand it is easy to shape things for easy readability. For instance, you
can always use built-up fractions and large operators (e.g., $\int$ and $\sum$), or put in plenty of extra spacing. For long complicated expressions, try first on scrap paper.

**With a general wordprocessor.** General word processors come with several fonts but most are not helpful for mathematics. In particular, *Do not attempt to create italic math using a regular (text) italic font.* In math italic, numbers, parentheses and operators are not slanted, but in text italic they are. To write math italic with a regular wordprocessor, you would have to go back and forth between roman and italic so often it would drive you crazy. Therefore, it is best to avoid italics entirely and use an alternative convention stemming from the days of typewriters without interchangeable type balls: Use a single font and put extra blank space around mathematical letters and expressions. For instance,

Consider the variables $x$ and $y$ in the equation $y = 2x+3$ for a line.

This convention won’t solve all your problems. Readers might still confuse $an$ and $an$. So another strategy is to change letters. If $an$ is showing up in your work, consider changing $a$ to $b$ throughout your paper.

While most general wordprocessors do not have a math italic font, they may have a symbol font, from which you can pick and choose some symbols you need. Or, often you can get some special symbols by hitting special keys simultaneously with letter keys. For instance, Control-A may give you alpha. Some other control or option combination may give you $\int$, but only in this small size. Check to see what math symbols are available. Anything that is not available just write in by hand.

If you use just one font, stay away from sans serif fonts like Helvetica (no squiggles on letters). In such fonts 1, 1 and $|$ are often identical, as are 0 and O and some other pairs. (Even in “good” fonts, some pairs of mathematical symbols look similar to the untrained eye. See the Symbols Appendix for a table of similar symbols that you should learn to distinguish.)

Almost every word processing system allows easy access to subscripts and superscripts, and you should use them. (Most general programs make these sub- and superscripts the same size as the main text, contrary to the usual mathematics convention, but don’t stop to worry about this.) However, write in by hand any mathematical expression that would take too long to do well by computer. At first, you will probably grossly underestimate the amount of space you need for hand insertion. You’ll discover this only after you have printed out what you think is going to be your final copy. But if the rest of your paper is written on a computer, it will be easy to output another copy with more space. Just don’t forget to write in everything you left out; as you do revisions this repetitive hand effort will be a bit of a pain.

When there are alternative forms for formatting an expression, *and they are more or less as easy to read*, choose the one that is easiest to do on the computer. For instance, any wordprocessor
can produce $a/b$, so use this form instead of $\frac{a}{b}$. However, don’t use a form that is hard to read even if it is a whole lot easier to type. It is better to write your expression by hand. For instance, never type (6), p. 147, into your paper; handwrite (5), p. 147, instead.

With mathematical writing software. You can create any sort of expression or display, but some will take you a lot of time. Try to find simple ways to express what you want (see p. 163). Better to do some display by hand than to spend a lot of time on it.

D. Creating Figures

If you are writing by hand, of course you do your figures by hand.

If you are writing on a computer, and you know how to use computer software to produce a good figure and place it into your paper, great, but this process is not easy. Therefore, it is fine if you insert your figures by hand. You’ll probably need more space than you first think. In these respects, figures are rather like complicated mathematical expressions.

Why should mathematical figures be hard, when computer paint and draw programs abound? Because these programs are not set up for mathematics. Paint programs are fine for drawing squiggly lines, but they may be too squiggly to represent functions. Paint and draw programs let you draw straight lines and circles, but can they make the lines perpendicular, or exactly tangent to a curve, or can they make the circle be inscribed in a triangle? It takes a lot of time with paint and draw programs to make mathematical figures look even approximately correct. And then there is labeling; paint and draw programs allow labels, but not with mathematical notation.

There are solutions. If you have a program that produces mathematical graphics (e.g., general mathematical software like Maple and Mathematica, or special purpose software like StatView and DataDesk for statistics and Geometer’s Sketchpad for plane geometry), you can usually cut and paste from those programs into your wordprocessor. But don’t be surprised if you need some graphic that these programs can’t produce, or can’t produce without a lot of work.

Just as there are complete mathematical typesetting programs, there are complete figure programs. E.g., Postscript can produce any imaginable graphic. However, such programs are hard to learn and cumbersome to use.

Suggestion: If you are an artist first and a math student second, then learn some powerful paint-and-draw programs, and use them to produce your figures. Otherwise, do all but the most standard figures by hand.