

**THIS IS THE TITLE**

by

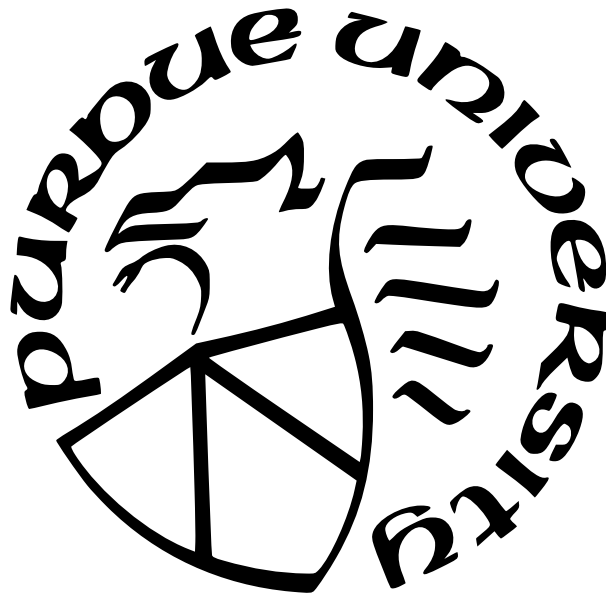
**Ima Author**

**A Thesis**

*Submitted to the Faculty of Purdue University*

*In Partial Fulfillment of the Requirements for the degree of*

**Doctor of Philosophy**



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To graduate students

## ACKNOWLEDGMENTS

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## PREFACE

This is the preface.

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## LIST OF SYMBOLS

$m$  mass

$v$  velocity

## ABBREVIATIONS

abbr	abbreviation
bcf	billion cubic feet
BMOC	big man on campus

## NOMENCLATURE

alanine 2-Aminopropanoic acid

gasoline a transparent, petroleum-derived flammable liquid that is used primarily as a fuel in most spark-ignited internal combustion engines [1]

valine 2-Amino-3-methylbutanoic acid

Valvoline Valvoline Inc. is an American manufacturer and distributor of Valvoline-brand automotive oil, additives, and lubricants. It also owns the Valvoline Instant Oil Change and Valvoline Express Care chains of car repair centers. As of 2016, it is the second largest oil change service provider in the United States with 10% market share and 1,050 locations. [2]

you can divide these into categories if you want

### **Biology**

alanine 2-Aminopropanoic acid

valine 2-Amino-3-methylbutanoic acid

### **Transportation**

gasoline a transparent, petroleum-derived flammable liquid that is used primarily as a fuel in most spark-ignited internal combustion engines [1]

Valvoline Valvoline Inc. is an American manufacturer and distributor of Valvoline-brand automotive oil, additives, and lubricants. It also owns the Valvoline Instant Oil Change and Valvoline Express Care chains of car repair centers. As of 2016, it is the second largest oil change service provider in the United States with 10% market share and 1,050 locations. [2]





## ABSTRACT

PurdueThesis is a L<sup>A</sup>T<sub>E</sub>X document class used for master's bypass reports, master's theses, PhD dissertations, and PhD preliminary reports. This template demonstrates how to use PurdueThesis.

## 1. IMPORTANT—READ THIS FIRST

Be sure to sign up for the [PurdueThesis mailing list](#)<sup>[4]</sup> to learn of important changes to or get help with PurdueThesis.

I suggest you do not make any changes to the `PurdueThesis.cls` file. Put any changes in the `thesis.tex` file if you can. That way you will not need to add your customizations when a new version of `PurdueThesis.cls` is released.



## 2. INTRODUCTION

### 2.1 Typographic Conventions

The following typographic conventions are used in this document. These conventions were influenced by [5–7]. There are no quotes in the typographic conventions.

*Emph*, *FirstTime*, and *Title*

Emphasized material, terms used for the first time, and titles are typeset in italics.

Here are some examples: Emphasis: You *must* do this. First Time Use: An *ekayak* is an electric kayak. Title: He read *The Grapes of Wrath* and watched *Citizen Kane*.

`Keyboard` `Keys` and `Screen` `Buttons`

Keyboard keys look like keyboard keys. `Control` + `A` means press the Control key and A key at the same time. `A` `B` means press the A key and then press the B key. Screen Buttons look like screen buttons.

**Literal Element**

Literal elements are typeset in a typewriter font. Literal elements include checkboxes, code, environment variables, file names, function names, L<sup>A</sup>T<sub>E</sub>X input, output, variable names, and verbatim input (except for commands typed on the command line). `␣` is used to indicate a space if it is not clear where spaces are.

`Menu` `»` `Submenu` `»` `Item`

Menus are typeset as arrows pointing to the right. For example, to make sure smooth scrolling is on go to `Edit` `»` `Settings` and make sure the `Use smooth scrolling` checkbox is checked.

*Placeholder*

Placeholders are typeset in a slanted font. Placeholders need to be replaced with real input.

**shell command**

Shell commands are typeset in a bold typewriter font. Shell commands are typed on the command line by the user.

## 2.2 Writing in English Information

### 2.2.1 Don't use redundant acronyms

Don't use redundant acronyms [8–15] like the following in formal writing:

**Table 2.1.** Redundant Acronyms

<b>Redundant Acronym</b>	<b>Corresponding Phrase</b>
% APR	percent Annual Percentage Rate
ABS system	Antilock Braking System system
AC current	Alternating Current current
ACT test	American College Test test
ADD disorder	Attention Deficit Disorder disorder
AIDS syndrome	Acquired Immune Deficiency Syndrome syndrome
AM modulation	Amplitude Modulation modulation
APL language	A Programming Language language
APR rate	Annual Percentage Rate rate
ATM machine	Automated Teller Machine machine
BASIC code	Beginner's All-Purpose Symbolic Instruction Code code
CAD design	Computer-Aided Design design
CD disc	Compact Disc disc
CNN news network	Cable News Network news network
COBOL language	Common Business-Oriented Language language
DC Comics	Detective Comics Comics
DC current	Direct Current current
DVD disk	Digital Versatile Disk disk
DMZ zone	DeMilitarized Zone zone
FOD damage	Foreign Object Damage damage
GIF format	Graphics Interchange Format format [16]
GMT time	Greenwich Mean Time time [17]
GPS system	Global Positioning System system [18]
GOP party	Grand Old Party party [19]
GRE exam	Graduate Record Examination exam [20]
HIV virus	Human Immunodeficiency Virus virus [21]
HTML language	HyperText Markup Language language [22]
IRA account	Individual Retirement Account account [21]
ISBN number	International Standard Book Number number
ISDN network	Integrated Services Digital Network network
LAN network	Local Area Network network
LCD display	Liquid Crystal Display display
LED diode	Light Emitting Diode diode
LEM module	Lunar Excursion Module module

*continued on next page*

Table 2.1. *continued*

Redundant Acronym	Corresponding Phrase
MLB baseball	Major League Baseball baseball [23]
MIDI interface	Musical Instrument Digital Interface interface
MLS soccer	Major League Soccer soccer [23]
NATO organization	North Atlantic Treaty Organization organization
NPR radio	National Public Radio radio
OPEC countries	Organization of Petroleum Exporting Countries countries
PAC committee	Political Action Committee committee
PC computer	Personal Computer computer
PDF format	Portable Document Format format [24]
PIN number	Personal Identification Number number
RAM memory	Random-Access Memory memory
SSN number	Social Security Number number [25]
TCP-IP protocol	Transmission Control Protocol/Internet Protocol protocol
UPC code	Universal Product Code code
UL laboratories	Underwriters Laboratories laboratories
VAT tax	Value Added Tax tax
VHF frequency	Very High Frequency frequency
VIN number	Vehicle Identification Number number

I sometimes use FBI (Federal Bureau of Investigation) as an adjective, e.g., ‘an FBI investigation’.

The SAT (SAT is not an acronym) is a standardized test [26].

### 2.2.2 Logical punctuation

I use logical punctuation [27]:

The sign said “Buses Only”.

instead of

The sign said “Buses Only.”

so quoted material, and only quoted material, is inside quotes. This is relatively new and not many people use it. Your major professor may not like this style. Check with them before you decide to use this.

### 2.2.3 Serial comma

I use the serial comma:

apple, berry, and cherry

instead of

apple, berry and cherry

because I find it easier to see the list items when they are separated by commas. The serial comma is also known as the Oxford comma, Harvard comma, or series comma.

### 2.2.4 Modern pronouns

I don't use modern pronouns in this document but if I did I'd use the LambdaMoo “spivak” (1991) [28] variant of gender-neutral pronouns. (Hmm...thinking machines are coming. People are anthropocentric [29]. There may be resistance to using traditional human pronouns for machines that think. I wonder if using traditional pronouns for mostly-meatbag lifeforms and spivak pronouns for mostly non-meatbag lifeforms would make sense.)

<b>Variant</b>	<b>Subject</b>	<b>Object</b>	<b>Possessive adjective</b>	<b>Possessive pronoun</b>	<b>Reflexive</b>
<b>Masculine</b>	he said	I saw him	his leg hurt	that is his	he hurt himself
<b>Feminine</b>	she said	I saw her	her leg hurt	that is hers	she hurt herself
<b>LambdaMoo “spivak” (1991)</b>	e said	I saw em	eir leg hurt	that is eirs	e hurt emself

## 2.3 The software used

Prof. Donald Knuth of Stanford University wrote the  $T_{E}X$  typesetting system for the creation of beautiful books—and especially for books that contain lots of mathematics [30, page v]. He wasn't happy with the quality of the typesetting in his multi-volume *The Art of Computer Programming*.  $T_{E}X$  was first released in 1978.  $T_{E}X$ -related systems are not ‘What You See Is What You Get’ (WYSIWYG) systems. Documents are created in an ordinary text editor and processed by a program to make the output. This is a nice feature

because one can concentrate on the content of the document instead of the appearance of the document.

Dr. Leslie Lamport extended  $\text{T}_{\text{E}}\text{X}$  using  $\text{T}_{\text{E}}\text{X}$ 's programming language to make the easier-to-use  $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ . It was first released in 1984. The  $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$  Project [31] now handles  $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$  development.

*Lua $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$*  is a dialect of  $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$  with features that make it easier to use for programming.

*T<sub>E</sub>X Live* [32] is a free  $\text{T}_{\text{E}}\text{X}$  software distribution that contains all of the above software and more. This document was created using  $\text{T}_{\text{E}}\text{X}$  Live.  $\text{T}_{\text{E}}\text{X}$  Live is available for Linux, Unix, and Windows. *MacT<sub>E</sub>X* is a  $\text{T}_{\text{E}}\text{X}$  Live-based system for Apple MacOS computers. *Overleaf* is a  $\text{T}_{\text{E}}\text{X}$  Live-based system to run  $\text{T}_{\text{E}}\text{X}$  on the web.

*PurdueThesis* (*PuTh* for short—rhymes with tooth) uses  $\text{LuaL}^{\text{A}}\text{T}_{\text{E}}\text{X}$  to make it easier to do Purdue theses, dissertations, etc. This template demonstrates how to use *PurdueThesis*. *PurdueThesis* is intended to support all Purdue campuses, programs, and graduate degrees. I only support this software using  $\text{T}_{\text{E}}\text{X}$  Live.

Figure 2.1 shows the  $\text{LuaL}^{\text{A}}\text{T}_{\text{E}}\text{X}$  system flowchart. *Overleaf* [33] uses `latexmk` [34] to run `bibtex`, `makeindex`, and `lualatex` automatically so the minimum amount of work is done. On Linux, MacOS, and Windows you can run the programs individually or use `latexmk`—I recommend using `latexmk`.

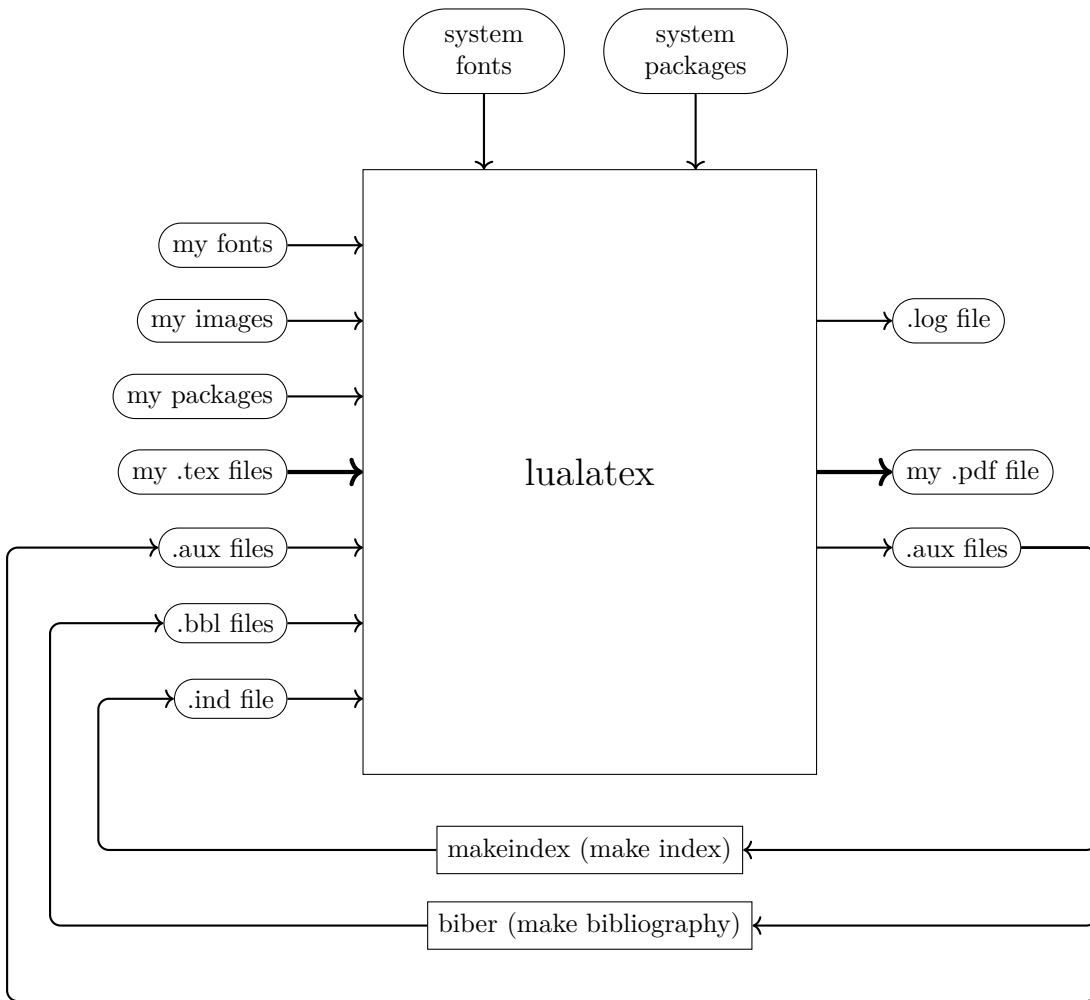
The Thesis and Dissertation Office [35] wrote a formatting manual [36] and Microsoft Word templates [37] for Purdue theses, etc.

## 2.4 $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ -related information

### 2.4.1 Input reading rules

$\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$  uses the following rules when reading input:

- Spaces at the beginning of a line are ignored.
- `%` starts a comment. The `%` and everything after it on that line are ignored. Type `\%` to print a ‘%’.
- `Enter` is equivalent to a space.



**Figure 2.1.** Lua<sub>l</sub>TeX System Flowchart

- `Enter` `Enter` (a blank line) ends a paragraph.
- Typing multiple spaces works the same as one space.

## 2.4.2 Input preparation conventions

In  $\text{\LaTeX}$  typing

As  $\backslash(h\backslash)$  approaches 0 in the limit, the last fraction can be shown to go to zero. This is true because the area of the red portion of excess region is less than or equal to the area of the tiny black-bordered rectangle. More precisely,  $\backslash[\backslashleft|f(x)-\frac{A(x+h)-A(x)}{h}\backslashright|-\frac{\backslashleft|\text{Red Excess}\backslashright|}{h}\leq\frac{h\backslashbig(f(x+h_1)-f(x+h_2)\backslashbig)}{h}=f(x+h_1)-f(x+h_2),\backslash]$  where  $\backslash(x+h_1\backslash)$  and  $\backslash(x+h_2\backslash)$  are points where  $\backslash(f\backslash)$  reaches its maximum and its minimum, respectively, in the interval  $\backslash([x,x+h]\backslash)$ .

gives exactly the same output as

As  $\backslash(h\backslash)$  approaches 0 in the limit, the last fraction can be shown to go to zero. This is true because the area of the red portion of excess region is less than or equal to the area of the tiny black-bordered rectangle. More precisely,

$$\backslash[\backslashleft|f(x)-\frac{A(x+h)-A(x)}{h}\backslashright|-\frac{\backslashleft|\text{Red Excess}\backslashright|}{h}\leq\frac{h\backslashbig(f(x+h_1)-f(x+h_2)\backslashbig)}{h}=f(x+h_1)-f(x+h_2),\backslash]$$

where  $\backslash(x+h_1\backslash)$  and  $\backslash(x+h_2\backslash)$  are points where  $\backslash(f\backslash)$  reaches its maximum and its minimum, respectively, in the interval  $\backslash([x, x + h]\backslash)$ .

I've used L<sup>A</sup>T<sub>E</sub>X over 30 years and use these personal conventions to prepare input. Using these conventions leads to many short lines, but I find those easier to read and edit. Do whatever works best for you.

start input lines with

the first word of a sentence

(

and

but

from

or

to

end input lines with

sentence-ending periods

phrase-ending commas

phrase-ending colons

phrase-ending semicolons

)

\\

\\[*dimension*]

put these on a line of their own

`\begin{environment name}`

`\end{environment name}`

short parenthetical remark

## 2.5 Filenames

There are several different name styles for file names:



Name	Why it's called that
camelCase	C is taller than surrounding characters, looks like camel's hump
kebab-case	letters appear to be slid on shish-kebab skewer, no <code>[Shift]</code> needed
PascalCase	popular in the Pascal programming language
snake_case	looks like a snake, is kebab-case except - is changed to _

I recommend you only use kebab-case file names that consist of only lowercase letters, zero or more digits, zero or more - characters (but no consecutive - characters), and a single period. You won't need to use `[Shift]` then.

Do not put spaces in your file names. It makes it easier to run your thesis on other computer operating systems. Linux, MacOS, and Windows are operating systems.

I like to start all chapter file names with `ch-`. Chapter names are everything from the beginning of the thesis through the last chapter. Chapters include all front matter in addition to all chapters.

Appendix names start with `ap-` and are everything after the last chapter including any bibliography, colophon, indices, and vita.

Graphics files specific to your thesis start with `gr-` and go in the graphics folder. Non-thesis graphics files retain their normal names and go in the graphics folder.

L<sup>A</sup>T<sub>E</sub>X package files specific to your thesis start with `pa-` and go in the packages folder. Non-thesis packages retain their normal names and go in the packages folder.

## 2.6 Special input characters

These input characters are special:

#	\$	%	&	\	^	_	{	}	~	
Type										
	<code>\#</code>	<code>\\$</code>	<code>\%</code>	<code>\&amp;</code>	<code>\backslash\$</code>	<code>\char'136</code>	<code>\_</code>	<code>\{</code>	<code>\}</code>	<code>\char'176</code>
to get this output										
	#	\$	%	&	\	^	_	{	}	~

## 2.7 Spacing after periods

A lowercase letter followed by a period is treated like the end of a sentence with approximately two spaces following the period. To not make it the end of a sentence put `\` or `~` after the period. See table below.

An uppercase letter followed by a period is treated like a person's middle initial with approximately one space following the period. To make it the end of a sentence put `\@` before the period. See table below.

Input	Output	Comment
Dr. Smith	Dr. Smith	too much space after Dr.
Dr.\ Smith	Dr. Smith	correct, Dr. and Smith can be on different lines
Dr.~Smith	Dr. Smith	correct, Dr. and Smith will be on same line, I recommend using this
at NASA. The	at NASA. The	not enough space after NASA.
at NASA\@. The	at NASA. The	correct

(I thought the following was too confusing. One or more *lowercase/uppercase* letters followed by a period is treated like *the end of a sentence/a person's middle initial* with approximately *two/one* space(s) following the period.)

(I thought some people might think the following is too informal or nonstandard. It is pretty confusing also. One or more <sup>uppercase</sup>/<sub>lowercase</sub> letters followed by a period is treated like a middle initial <sup>uppercase</sup>/<sub>lowercase</sub> with approximately <sup>one</sup>/<sub>two</sub> space(s) following the period.)

## 2.8 Five kinds of dashes

There are five kinds of dashes

Name	Input	Output	Width in Points (72.27 points/inch)
hyphen	- (one hyphen)	-	3.91667pt
endash	-- (two hyphens)	–	5.87498pt
emdash	--- (three hyphens)	—	11.75pt
figure dash	\FigureDash	-	5.87498pt
minus sign	\(-\)	–	9.33336pt

**hyphen** The hyphen is a punctuation mark used to join words and to separate syllables of a single word [38].

Input	Output	Comment
- (one hyphen)	-	
son-in-law	son-in-law	used to join words
gas-oline	gas-oline	used to separate syllables, $\LaTeX$ hyphenates words automatically so you may not ever use this

**endash** The endash [39] is used for

Input	Output	Comment
-- (two hyphens)	–	
The Purdue--IU game	The Purdue–IU game	conflict
Perth--Dubai--Boston	Perth–Dubai–Boston	connection
Teal Road runs East--West	Teal Road runs East–West	direction
ages 21--65	ages 21–65	age range
June--July 1967	June–July 1967	month range
pages 38--55	pages 38–55	page range
1:15--2:15 p.m.	1:15–2:15 p.m.	time range
Purdue beat IU 35--28	Purdue beat IU 35–28	scores

**emdash** The emdash [40] is used for

---	(three hyphens)	—
<b>Input</b>	the usual suspects---	Larry, Moe, and Curly
<b>Output</b>	the usual suspects—	Larry, Moe, and Curly
<b>Comment</b>	—	acts like colon
<b>Input</b>	Larry, Moe, and Curly---	the usual suspects
<b>Output</b>	Larry, Moe, and Curly—	the usual suspects
<b>Comment</b>		inverse function of colon
<b>Input</b>	three people---	Larry, Moe, and Curly---%
<b>Output</b>	three people—	Larry, Moe, and Curly—are the usual suspects
<b>Comment</b>	first —	acts as (, second — acts as )
<b>Input</b>	I believe I shall---	no, I'm going to do it.
<b>Output</b>	I believe I shall—	no, I'm going to do it.
<b>Comment</b>	use —	when a thought evolves on the fly

Emdashes should be used sparingly in formal writing.

**figure dash** The figure dash (input: `\FigureDash`) is used to separate digits—it’s the same width as a digit and is used in identification numbers, part numbers, phone numbers, etc. Type, for example, `Q6759\FigureDash 18100` to get “Q6759-18100”.

**minus sign** Used for negative numbers or subtraction in math mode.

<b>Input</b>	<b>Output</b>	<b>Comment</b>
<code>-</code>	$-$	(one hyphen in text math mode or display math mode)
<code>\(-a + b\)</code>	$-a + b$	negative $a$
<code>\(a - b\)</code>	$a - b$	subtraction

## 3. SUMMARY

This is the summary chapter.

### 3.1 First Section

This is the first section of the summary chapter.

```
1 \chapter{SUMMARY}
2
3 This is the summary chapter.
4
5
6 \section{First Section}
7
8 This is the first section of the summary chapter.
```

## 4. RECOMMENDATIONS

Buy low. Sell high.

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## A. ABOUT THE APPENDICES

**These appendices are single-spaced to save space. Your thesis should use the default 1.5 line spacing.**

There are two groups of appendices. The first group are general appendices; the second group are domain-specific appendices.

These appendices are a series of examples. They are a work in progress.

Each example consists of some  $\LaTeX$  output followed by the corresponding input lines. Some  $\LaTeX$  input lines only define things and don't produce any output. Each chunk in the input file begins with `\begin{VerbatimOut}{z.out}` then has the  $\LaTeX$  input for the example, and ends with `\end{VerbatimOut}`, followed by a blank line, followed by a line that begins with `\My`.

```
1 \chapter{ABOUT THE APPENDICES}
2
3 % Use single spacing in the appendices from now on to save space.
4 \ZZbaselinestretch{1}
5
6 \textcolor{red}{%
7   \textbf{%
8     These appendices are single-spaced to save space.
9     Your thesis should use the default-1.5 line spacing.%
10  }}%
11 }
12
13 There are two groups of appendices.
14 The first group are general appendices;
15 the second group are domain-specific appendices.
16
17 These appendices are a series of examples.
18 They are a work in progress.
19
20 Each example consists of some  $\LaTeX$  output
21 followed by the corresponding input lines.
22 Some  $\LaTeX$  input lines only define things
23 and don't produce any output.
24 Each chunk in the input file begins with
25 \verb+\begin{VerbatimOut}{z.out}+
26 then has the  $\LaTeX$  input for the example,
27 % Don't literally end VerbatimOut on next line.
28 and ends with {\tt \char'134 end\char'173 VerbatimOut\char'175},
29 followed by a blank line,
30 followed by a line that begins with
31 \My.
32
```

### A.1 Paragraphs

This is the first paragraph. Paragraphs are separated by blank lines.

This is the second paragraph.

## A.2 Section Heading

This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

### A.2.1 Subsection heading

This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

#### Subsubsection heading

This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```
1
2
3 \section{Paragraphs}
4
5 This is the first paragraph.
6 Paragraphs are separated by blank lines.
7
8 This is the second paragraph.
9
10
11 \section{Section Heading}
12
13 This is a sentence.
14 This is a sentence.
15 This is a sentence.
16 This is a sentence.
17 This is a sentence.
18
19
20 \subsection{Subsection heading}
21
22 This is a sentence.
23 This is a sentence.
24 This is a sentence.
25 This is a sentence.
26 This is a sentence.
27
28
29 \subsubsection{Subsubsection heading}
30
31 This is a sentence.
32 This is a sentence.
33 This is a sentence.
34 This is a sentence.
35 This is a sentence.
```

### A.3 Text math

If items in a list are narrow like these Greek characters,

$\alpha$ ,  $\beta$ , and  $\gamma$

I'd input the line like this

$\alpha$ ,  $\beta$ , and  $\gamma$

where the  $\sim$  is a tie that ties together what's before and after it on the same line of the output [30, page 92].

This text is the correct length to show what happens with and without ties:  $\alpha$ ,  $\beta$ , and  $\gamma$ . See how the line gets split and the  $\gamma$  is at the beginning of the line?

This text is the correct length to show what happens with and without ties:  $\alpha$ ,  $\beta$ , and  $\gamma$ . See how the line gets compressed a little bit so the  $\gamma$  is not at the beginning of the line?

```
1
2
3 \section{Text math}
4
5 If items in a list are narrow like these Greek characters,\
6 \I2 \verb+\alpha$, \beta$, and \gamma$+\
7 I'd input the line like this\
8 \I2 \verb+\alpha$,~\beta$, and~\gamma$+\
9 where the \verb+~+ is a tie
10 that ties together what's before and after it on the same line of the output
11 \cite[page~92]{knuth2012}.
12
13 This text is the correct length to show what happens with and without ties:
14 \alpha$,
15 \beta$,
16 and \gamma$.
17 See how the line gets split
18 and the~\gamma$ is at the beginning of the line?
19
20 This text is the correct length to show what happens with and without ties:
21 \alpha$,~\beta$,
22 and~\gamma$.
23 See how the line gets compressed a little bit so the~\gamma$
24 is not at the beginning of the line?
```

## B. ACCESSIBILITY

```
1 \chapter{ACCESSIBILITY}
2 \ix{accessibility//Accessibility appendix}
```

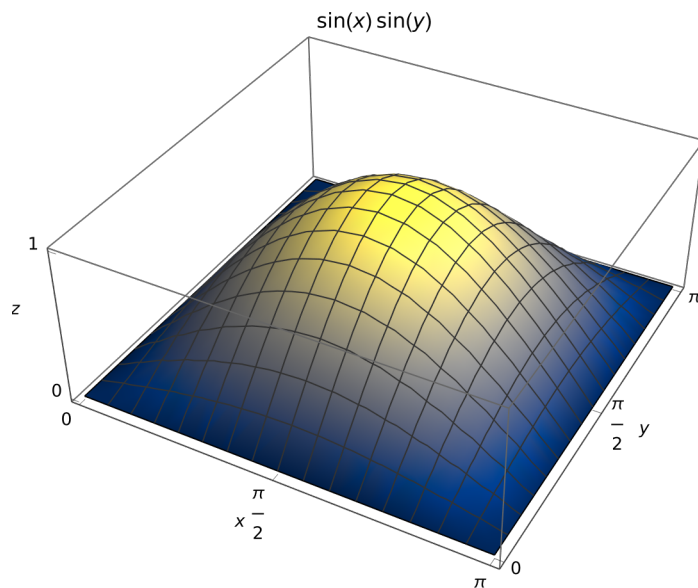
Accessibility is the design of products, devices, services, vehicles, or environments so as to be usable by people with disabilities. [41]

```
1
2 Accessibility is the design of products,
3 devices,
4 services,
5 vehicles,
6 or environments
7 so as to be usable by people with disabilities.
8 \cite{wikipedia-accessibility}
```

Please use the cividis colormap for accessibility unless there is a good reason not to.

### B.1 Color

Color vision deficiency (CVD) affects more than 4% of the population and leads to a different visual perception of colors. The cividis colormap is optimal for viewing by those with or without CVD [42]. The *Cividis Mathematica Example Notebook* [43] and *Cividis Mathematica Example Notebook PDF file* [44] contain the Mathematica code used to produce this cividis example:



```
1
2
3 \section{Color}
4
5 Color vision deficiency (CVD) affects more than 4% of the population
6 and leads to a different visual perception of colors.
7 The cividis%
```

```
8 \ix{cividis colormap}
9 colormap is optimal
10 for viewing
11 by those with or without CVD
12 \cite{nunez2018}.
13 The
14 \citetitle{senn2022}
15 \cite{senn2022}
16 and
17 \citetitle{senn2022b}
18 \cite{senn2022b}
19 contain the Mathematica code used to produce this cividis example:\[\baselineskip]
20 \includegraphics{gr-cividis.pdf}
```

## B.2 PDF file

The L<sup>A</sup>T<sub>E</sub>X Project [31] is working on making tagged and accessible PDF files with L<sup>A</sup>T<sub>E</sub>X [45]. It was not finished as of December 23, 2022.

```
1
2
3 \section{PDF file}
4
5 The \LaTeXLogo\ Project
6 \cite{thelateproject2023}
7 is working on making tagged
8 and accessible PDF files with \LaTeXLogo\ %
9 \cite{mittlebach2022}.
10 It was not finished as of December 23, 2022.
```

## C. BUGS

This appendix lists all bugs/comments/issues/etc. under the generic name ‘bug’. Each bug is assigned a number when I learn of it. Bug numbers are 1, 2, . . . . I started keeping track of bugs in this fashion on February 26, 2022, and some previously known bugs are included in this list. A color indicates a bug’s priority:

<u>Description</u>	<u>Color</u>
done or waiting on someone else	black
high priority or easy to do	red
low priority	blue
not prioritized yet	gray

See the `ap-bugs.tex` file for the Lua $\text{\LaTeX}$  input for this appendix.

### C.1 These bugs need to be looked at

**BUG 1.** Table of Contents is double-spaced instead of 1½ spacing. Tighten up section and less significant headings spacing? Reported by Anita Adams Sale on 2021-03-17.

**BUG 6.** APA reference style indents references too far on left. Reported by Mark Senn on 2021-04-08.

**BUG 8.** Use, for example, `Last Accessed: yyyy-mm-dd. urldate` in bibliography. Reported by Mark Senn on 2021-04-19.

**BUG 13.** Headings containing a SmallCaps font do not work. Reported by Javad (Nima) Darivandpour on 2021-06-29. See [T.5](#).

**BUG 14.** On Overleaf only, when using `\def\ZZshowtimestamp{true}`, the time and sometimes the date are wrong at the top of the page. Reported by Mark Senn on 2022-02-25.

**BUG 15.** Left reference section margin is ok if a person has 10–99 references. Figure out how to adjusting margin for 1–9 or over 99 references. Reported by Mark Senn on unknown date.

**BUG 19.** Bibliography and References missing from navigation panel. Reported by Mark Senn on 2022-02-28. REFERENCES was in navigation panel on 2022-08-26.

**BUG 20.** Bibliography and References should be in all caps. Reported by Mark Senn on 2022-02-28. REFERENCES was in all caps on 2022-08-26.

**BUG 21.** IE students should be able to specify IEEE or APA bibliography format. Reported by Patrick Brunese on 2022-03-04.

**BUG 24.** Add A Dissertation Proposal document type. Add A Thesis Proposal document type. Reported by Mark Senn on 2022-12-20.

**BUG 25.** Dissertations and theses should continue to have *Month year* where *Month* is August, December, or May. For everything except dissertations and theses allow *Month year* or *Month day, year* dates where *Month* is any month. Reported by Mark Senn on 2022-12-20.

**BUG 26.** Complete HOW TO DEBUG L<sup>A</sup>T<sub>E</sub>X PROBLEMS chapter. Reported by Mark Senn on 2023-01-11.

**BUG 28.** Move `\addbibresource` from `PurdueThesis.cls` to `thesis.tex` to be more user friendly. Reported by Panos Manganaris on 2023-06-15.

**BUG 29.** Main bibliography and chapter bibliography should be indented the same amount. Reported by Panos Manganaris on 2023-06-15.

**BUG 30.** Main bibliography and chapter bibliography should both be flush with the left margin. Reported by Mark Senn on 2023-06-19.

**BUG 31.** There needs to be way to put a list of publications in a publications section. Reported by Panos Manganaris on 2023-06-14. Mark Senn is working on a way to do that using `keywords = {publication}` in a BibL<sup>A</sup>T<sub>E</sub>X `.bib` file entry.

**BUG 33.** Create Color Vision Deficiency (CVD) Accessible Line Graphs. IEEE Author Center <ieee-author-center@deliver.ieee.org> wrote on 2024-03-20:

Approximately 1 in 12 men and 1 in 200 women have color vision deficiency. It is highly likely that someone reading your article may have difficulty distinguishing between red and green, blue and green, or yellow and red. The following tips will help you communicate better with those readers.

- Use both color and shape to convey the same meaning; for example, solid and dashed lines or different fill patterns can help readers understand the figure without relying solely on color
- Each line of your line graph should be a thick line with a unique data point symbol. Contrast different elements of the figure with both color and brightness
- Connect the data label to the data line rather than relying on a color key

A quick way to evaluate your figure is to print it out in greyscale and see if it can still be interpreted correctly; if not, use some of these tips to more effectively communicate with all readers.

Lisa Renee Williams <will2922@purdue.edu> of the Graduate School wrote on 2024-03-21:

I think this is a wonderful idea and am in support of including information within the template to provide students the opportunity to use CVD.

**BUG 34.** Implement `\begin{chapterabstract}` and `\end{chapterabstract}` for abstracts within chapters. Maybe rename this `paperabstract`? Reported by Mark Senn on 2024-04-09.

**BUG 36.** Improve the order of thesis parts error message to indicate that not all parts listed are required. Reported by Mark Senn on 2022-09-21.

**BUG 37.** Check the spacing after all chapter and non-chapter headings for consistency. Reported by Mark Senn on 2020-02-28.

**BUG 38.** Add short caption info to documentation. See [Shortening captions for a list of illustrations](#) for a suggestion regarding this. To do this in L<sup>A</sup>T<sub>E</sub>X do



`\caption[short caption]{long caption}`

Reported by Mark Senn on 2023-12-08.

**BUG 39.** Page links for longtables don't link to right place from List of Tables. Example: Table R.6. Reported by Tunazzina Islam on 2025-01-27. *This may work with `hyperref.sty > 7.01h` in `TeX Live 2025`.*

## C.2 These bugs are waiting on a reply from someone other than Mark Senn

**BUG 10.** Using `linktoc = section` does not work with captions with `\frac`. Reported by Mark Senn on 2021-05-27. In the short-term, check with Ashlee Messersmith if `linktoc = page` can be used. If that's ok make the change and look into changing captions from my code to L<sup>A</sup>T<sub>E</sub>X's code. Waiting on Ashlee Messersmith.

## C.3 These bugs have been answered, fixed, or rejected

**BUG 2.** List of Figures indented  $\approx 1/4$  inch more than List of Tables. Reported by Anita Adams Sale on 2021-03-17. Still happening on 2021-11-30. Looked ok on 2022-08-26 but I think this problem is probably intermittent. Keep Ashlee Messersmith, Anita Adams Sale, and Sherrie Tucker informed. Adam Behnke sent me the solution to this problem on 2023-03-27.

**BUG 3.** Use “Last Accessed: dd/mm/yy.” `urldate` in bibliography. Reported by Priyank Kalgaonkar on 2021-04-06. Answered by Mark Senn on 2022-02-27.

The United States uses mm/dd/yy and other countries use dd/mm/yy [46]. I recommend using what your bibliography style defines or the unambiguous ISO 8601 standard yyyy-mm-dd [47].

**BUG 4.** Change citation, e.g., [6], [71] to [6,71]. Reported by Mark Senn on 2021-04-07. Fixed on 2022-04-14. Tested ok on 2022-04-14.

**BUG 5.** Change citation, e.g., [6], [7], [8] to [6–8]. Reported by Mark Senn on 2021-04-07. Fixed on 2022-04-14. Tested ok on 2022-04-14.

**BUG 7.** Non-nested description environments have bold items. Nested description environments have non-bold items. How come? Are the indentations correct? Reported by Mark Senn on 2021-04-09. Tested ok on 2021-05-31.

**BUG 9.** Check that `@{}` is before the left column and after the right column in all tables. Reported by Mark Senn on 2021-04-19. Tested ok on 2022-10-18 using

```
alias g=grep
```

```
g -P '\s*\begin{tabular}' *.tex | g -Pv '^.*?:\s*\begin{tabular}{@{}}.*@{}
```

**BUG 11.** Bibliography change: Change, for example, “Acoustical Science and Technology, vol. 23, no. 1” to “Acoustical Science and Technology **23** (1)”. Reported by Daniel Joesph Carr on 2021-06-16. Answered by Mark Senn on 2022-10-18.

The “IEEE Reference Guide” [48, page 12] specifies that `vol.` and `no.` should be used. You are the only one that has requested this. I'm not going to change anything because of that. I like the

succinct “**23 (1)**” format but am not going to implement it because not everyone will know those are the journal volume and number.

**BUG 12.** Bibliography change: Change, for example, M. Abramowitz and I.A. Stegun, Eds., to M. Abramowitz and I.A. Stegun, editors, Reported by Daniel Joesph Carr on 2021-06-16. Answered by Mark Senn on 2022-10-18.

The “IEEE Reference Guide” [48, page 5] specifies that Ed. for a single editor and Eds. for multiple editors be used.

You are the only one that has requested this. I’m not going to change anything because of that.

But, if you put the current ieee.bbx file in the same directory as your thesis and change editor = Ed\adddot to editor = editor\adddot and editors = Eds\adddot to editors = editors\adddot it may do what you want. Email latex@ecn.purdue.edu if you need the current ieee.bbx file. I have not tested this answer.

**BUG 16.** Add DTECH degree. Reported by Mark Senn on unknown date. Program “Technology” and degree “Doctor of Technology” worked ok on 2022-08-26.

**BUG 17.** Allow , (comma) in \title. Reported by Mark Senn on unknown date. Tested ok on 2021-11-30.

**BUG 18.** Allow \ in \title. Reported by Mark Senn on unknown date. Tested ok on 2021-11-30.

**BUG 22.** \H{o} works in pdfL<sup>A</sup>T<sub>E</sub>X but does not work in LuaL<sup>A</sup>T<sub>E</sub>X. Reported by Raymond Polak III on 2022-10-28. Use \H{o} to get ó in the text. Use \ZZH{o} to get ő in the bibliography. Tested ok on 2023-03-27.

**BUG 23.** The Department of Human Development and Family Studies was renamed to Department of Human Development and Family Science. Reported by Mark Senn on 2022-12-03. Fixed on 2024-06-12.

**BUG 27.** The figures in subsections [L.5.2](#) and [L.5.3](#) are

Color	On Operating Sytem	Using
color	macOS 12.6.2	Firefox 108.0.2 (64-bit)
color	Ubuntu 22.04 LTS	evince (GNOME Document Viewer 42.3)
black and white	Ubuntu 22.04 LTS	Firefox 108.0.2 (64-bit)

Reported by Mark Senn on 2023-01-11. Use software that will show the colors correctly.

**BUG 32.** The first two pages of the thesis (the title page and the graduate school statement of committee approval) should have a top margin of 1 1/2 in. Reported by Lisa Williams on 2023-12-08. Fixed on 2024-02-07. Tested ok on 2024-02-07.

**BUG 35.** Is there an easy way of dividing the thesis into multiple parts?

Asked by Vahid Tac on 2024-05-29. Thesis Help (Lisa Williams) <thesishelp@purdue.edu> wrote on 2024-06-04 “Since it is not part of the thesis structure in Purdue policies, we do not want parts...”.





## E. CHAPTER APPENDICES

Using `\chapterappendix` or `\chapterappendices` in a chapter will number sections, for example, 1.1, 1.2, ..., 1.A, 1.B, ... .

Using `\chapterappendix` or `\chapterappendices` in an appendix will number sections, for example, A.1, A.2, ..., A.A, A.B, ... .

I suggest only using `\chapterappendix` or `\chapterappendices` in chapters—using them in appendices is too confusing.

```
1 \chapter{CHAPTER APPENDICES}
2
3 Using |\chapterappendix|
4 or |\chapterappendices|
5 in a chapter will number sections,
6 for example,
7 1.1,
8 1.2,
9 \ldots,
10 1.A,
11 1.B,
12 \ldots\,.
13
14 Using |\chapterappendix|
15 or |\chapterappendices|
16 in an appendix will number sections,
17 for example,
18 A.1,
19 A.2,
20 \ldots,
21 A.A,
22 A.B,
23 \ldots\,.
24
25 I suggest only using |\chapterappendix|
26 or |\chapterappendices| in chapters---%
27 using them in appendices is too confusing.
```

## E.1 This is a section heading

This is a paragraph.

Use `\chapterappendix` or `\chapterappendices` to make sections until the end of the next chapter be appendices.

## E.A This is a chapter appendix

This is a paragraph.

```
1 \newpage
2
3
4 \section{This is a section heading}
5
6 This is a paragraph.
7
8 Use \verb+\chapterappendix+ or \verb+\chapterappendices+
9 to make sections until the end of the next chapter
10 be appendices.
11
12
13 \chapterappendix
14
15
16 \section{This is a chapter appendix}
17
18 This is a paragraph.
```

## F. CITATIONS AND REFERENCES

```
1 \chapter{CITATIONS AND REFERENCES}
```

In your thesis try to cite only original sources like articles and books. If possible, don't use encyclopedias and Wikipedia. [49]

```
1
2 In your thesis try to cite only original sources like articles
3 and books.
4 If possible,
5 don't use encyclopedias and Wikipedia.
6 \cite{citing-wikipedia}
```

This chapter contains information about citations and references—how to cite a reference in the text and the fine points of defining a bibliography (also called “References”) entry.

```
1
2 This chapter contains information about citations
3 and references---how to cite a reference in the text
4 and the fine points of defining a bibliography
5 (also called ‘References’)
6 entry.
```

### F.1 Citations

```
1
2
3 \section{Citations}
```

This @online entry does not have a date but has a urldate: [50].

“Diameters of point sets” by Paul Erdős [51] was published in 1992.

For L<sup>A</sup>T<sub>E</sub>X answers I refer to [52] and then to [53] or [54]. [54] is an update to [55].

```
1 This @online entry does not have a date
2 but has a urldate:
3 \cite{engineering}.
4
5 \citetitle{erdos1992}
6 by Paul Erd\H os
7 \cite{erdos1992}
8 was published in
9 \citeyear{erdos1992}.
10
11 For \LaTeX\ answers I refer to
12 \cite{lampport1994}
13 and then to
14 \cite{goossens1994}
15 or
16 \cite{kopka1999}.
17 \cite{kopka1999}
18 is an update to
19 \cite{kopka1995}.
```

Here is an example .bib file entry:

```

@misc{example2020,
  address   = {Imaginaryville, Indiana},
  author    = {Andrew Anteater and Bertha Bear and Charles Cheetah and Davida Deer
              and Ethan Eagle},
  date      = {2020-10-27},
  doi       = {00.0000/000-0-000-00000-0},
  editor    = {Mark Senn},
  edition   = {2},
  isbn      = {{000\FigureDash 0\FigureDash 000\FigureDash 00000\FigureDash 0}},
  publisher = {Bogus International Publishing Company},
  title     = {{Neil A.~Armstrong} Worked for {NASA}},
  url       = {https://bogus.com/bogus.html},
  urldate   = {2020-10-27},
  version   = {1.0},
}

```

```

1
2 Here is an example .bib file entry:
3
4 {\footnotesize
5 \begin{verbatim}
6 @misc{example2020,
7   address   = {Imaginaryville, Indiana},
8   author    = {Andrew Anteater and Bertha Bear and Charles Cheetah and Davida Deer
9               and Ethan Eagle},
10  date      = {2020-10-27},
11  doi       = {00.0000/000-0-000-00000-0},
12  editor    = {Mark Senn},
13  edition   = {2},
14  isbn      = {{000\FigureDash 0\FigureDash 000\FigureDash 00000\FigureDash 0}},
15  publisher = {Bogus International Publishing Company},
16  title     = {{Neil A.~Armstrong} Worked for {NASA}},
17  url       = {https://bogus.com/bogus.html},
18  urldate   = {2020-10-27},
19  version   = {1.0},
20 }
21 \end{verbatim}
22 }

```

Below are some example `ieeetex` style Bib<sub>La</sub>TeX citations.

(Different citation styles may give different results, for example, in the `apa` style, `\cite{example2020}` gives “Anteater et al., 2020” and `\parencite{example2020}` gives “(Anteater et al., 2020)”. See [56] for more information. I’ll document all the citation styles that `PurdueThesis` uses based on how `\ZZinstitution`, `\ZZcampus`, and `\ZZprogram` are set later.)



Input	Output
<code>\cite{example2020}</code>	[57]
<code>\cite*{example2020}</code>	[57]
<code>\citeauthor{example2020}</code>	Anteater <i>et al.</i>
<code>\citeauthor*{example2020}</code>	Anteater <i>et al.</i>
<code>\citedate{example2020}</code>	Oct. 27, 2020
<code>\citetitle{example2020}</code>	<i>John Doe is not employed by NASA</i>
<code>\citetitle*{example2020}</code>	<i>John Doe is not employed by NASA</i>
<code>\citeurl{example2020}</code>	<a href="https://bogus.com/bogus.html">https://bogus.com/bogus.html</a>
<code>\citeyear{example2020}</code>	2020
<code>\parencite{example2020}</code>	[57]
<code>\textcite{example2020}</code>	Anteater <i>et al.</i> [57]

```

1
2 Below are some example |ieee| style \BibLaTeXLogo\ citations.
3
4 (%)
5 Different citation styles may give different results,
6 for example,
7 in the |apa| style,\
8 |\cite{example2020}|
9 gives
10 ‘‘Anteater et al., 2020’’
11 and
12 |\parencite{example2020}|
13 gives
14 ‘‘(Anteater et al., 2020)’’.
15 See
16 \cite{apa-style-examples}
17 for more information.
18 I’ll document all the citation styles
19 that \PurdueThesisLogo\ uses based on how
20 |\ZZinstitution|,
21 |\ZZcampus|,
22 and |\ZZprogram| are set later.%
23 )
24
25 \begin{inlinetable}
26   \begin{tabular}{@{}l@{}}
27     \toprule
28     \textbf{Input}& \textbf{Output}\
29     \midrule
30     \verb+\cite{example2020}+& \cite{example2020}\
31     \verb+\cite*{example2020}+& \cite*{example2020}\
32     \verb+\citeauthor{example2020}+& \citeauthor{example2020}\
33     \verb+\citeauthor*{example2020}+& \citeauthor*{example2020}\
34     \verb+\citedate{example2020}+& \citedate{example2020}\
35     \verb+\citetitle{example2020}+& \citetitle{example2020}\
36     \verb+\citetitle*{example2020}+& \citetitle*{example2020}\
37     \verb+\citeurl{example2020}+& \citeurl{example2020}\
38     \verb+\citeyear{example2020}+& \citeyear{example2020}\
39     \verb+\parencite{example2020}+& \parencite{example2020}\
40     \verb+\textcite{example2020}+& \textcite{example2020}\
41     \bottomrule
42   \end{tabular}
43 \end{inlinetable}

```

## G. COMMON MISTAKES

The following Headings, Mathematics, and Text sections describe some common mistakes.

### G.1 Headings

Farkas [58, page 289] wrote

The practice of stacking headings is routinely condemned by style manuals and other authorities. Here is a typical statement, taken from Houghton Mifflin’s guidelines for authors.

Avoid “stacking” heads, or placing two levels of headings together without intervening text. A heading cannot substitute for the transitional or introductory paragraphs that guide the reader through a chapter. Remember too that a chapter opening looks better in type when one or more paragraphs of text precede the first heading.

```
1 \chapter{COMMON MISTAKES}
2
3 The following Headings, Mathematics, and Text
4 sections describe some common mistakes.
5
6
7
8
9 \section{Headings}
10
11 \textcite[page~289]{farkas2011}
12 wrote
13
14 \begin{quotation}
15   The practice of stacking headings
16   is routinely condemned by style manuals
17   and other authorities.
18   Here is a typical statement,
19   taken from Houghton Mifflin’s guidelines for authors.
20 \begin{quotation}
21   Avoid ‘‘stacking’’ heads,
22   or placing two levels
23   of headings together without intervening text.
24   A heading cannot substitute
25   for the transitional
26   or introductory paragraphs
27   that guide the reader through a chapter.
28   Remember too that a chapter opening looks better in type
29   when one
30   or more paragraphs
31   of text precede the first heading.
32 \end{quotation}
33 \end{quotation}
```

## G.2 Mathematics

### G.2.1 Put a little extra horizontal space before dx

```
1
2
3 \section{Mathematics}
4
5 \subsection{Put a little extra horizontal space before dx}
```

## G.3 Text

```
1
2
3 \section{Text}
```

### G.3.1 e.g.,

“e.g.” should always be followed by a comma.

```
1
2 \subsection{e.g.,}
3 \ix{e.g.}
4
5 ‘‘e.g.’’ should always be followed by a comma.
```

### G.3.2 “et al.” is an abbreviation

The phrase “et al.” is an abbreviation and should always be followed by a period. It should be in the normal font for your document—do not italicize or underline it.

Example:

input	Thun et al.~used data from Santa Claus.
output	Thun et al. used data from Santa Claus.
comment	my recommendation
input	Thun et al. used data from Santa Claus.
output	Thun et al. used data from Santa Claus.
comment	too much space after period— $\LaTeX$ thinks period is end of sentence
input	Thun et al\@. used data from Santa Claus.
output	Thun et al. used data from Santa Claus.
comment	spacing is right but the “et al.” could occur at end of a line

```
1
2 \subsection{‘‘et al.’’ is an abbreviation}
3 \ix{et al.}
4
5 The phrase ‘‘et al.’’
6 is an abbreviation
7 and should always be followed by a period.
8 It should be in the normal font for your document---%
```

```

9 do not italicize or underline it.
10
11 Example:\[6pt]
12 \indent\indent
13 \begin{tabular}{@{}l@{}}
14 input& \verb+Thun et al.-used data from Santa Claus.+\\
15 output& Thun et al.-used data from Santa Claus.\\
16 comment& my recommendation\[6pt]
17 input& \verb+Thun et al. used data from Santa Claus.+\\
18 output& Thun et al. used data from Santa Claus.\\
19 comment& too much space after period---\LaTeX\ thinks period is end of sentence\[6pt]
20 input& \verb+Thun et al\@. used data from Santa Claus.+\\
21 output& Thun et al\@. used data from Santa Claus.\\
22 comment& spacing is right but the ‘et al.’ could occur at end of a line\\
23 \end{tabular}

```

### G.3.3 i.e.,

“i.e.” should always be followed by a comma.

```

1
2 \subsection{i.e.,}
3 \ix{i.e.}
4
5 ‘i.e.’ should always be followed by a comma.

```

### G.3.4 ldots

Use “1, 2,  $\dots$ , 10” instead of “1, 2, ..., 10”

```

1
2 \subsection{ldots}
3
4 Use ‘1, 2, \ldots, 10’
5 instead of 1, 2, ..., 10’

```

### G.3.5 text math subscripts

If you are using an English word as a math subscript or subsubscript typeset it in a roman font like this ‘ $x_{\text{max}}$ ’ instead of ‘ $x_{max}$ ’.

```

1
2 \subsection{text math subscripts}
3
4 If you are using an English word
5 as a math subscript or subsubscript
6 typeset it in a roman font like this
7 ‘\(\x_{\text{max}}\)\)’
8 instead of
9 ‘\(\x_{max}\)\)’.

```

### G.3.6 ties

Change the space in ‘Dr. ’, ‘Fig. ’, ‘Mr. ’, ‘Mrs. ’, ‘Mx. ’, ‘Prof. ’, etc., to ‘~’ so the period will only be followed by one space and, for example, ‘Dr.’ and ‘Smith’ will be tied together so they won’t be split over two lines.

```
1
2 \subsection{ties}
3
4 Change the space in
5 ‘Dr. ’, ‘Fig. ’, ‘Mr. ’, ‘Mrs. ’, ‘Mx. ’, ‘Prof. ’, etc.,
6 to ‘\(\sim\)’ so the period will only be followed by one
7 space and, for example, ‘Dr.’ and ‘Smith’ will be tied
8 together so they won’t be split over two lines.
```

## H. DEFINING COMMANDS

The next paragraph demonstrates how to define and use a command.

Editors recommend that a chapter title should never be followed by a section heading without some intervening text. I suggest writing for readers. Break the rules if necessary.

```
1 \chapter{DEFINING COMMANDS}
2
3 The next paragraph demonstrates how to define and use a command.
4
5 \renewcommand{\t}[2]
6 {% The "{" hides the space caused by the newline. LaTeX ignores leading spaces on a line.
7 Editors recommend that a #1 should never be
8 followed by a #2 without some intervening text.
9 }
10
11 \t{chapter title}{section heading}
12 I suggest writing for readers.
13 Break the rules if necessary.
```

# I. DEPRECATED SOFTWARE

Deprecated means [59]

to withdraw official support for or discourage the use of (something, such as a software product) in favor of a newer or better alternative.

The following software is deprecated for use with PurdueThesis. Read the “Details” or “Used For” columns below for more information.

```
1 \chapter{DEPRECATED SOFTWARE}
2
3 Deprecated means
4 \cite{merriam-webster-deprecated}
5 \begin{quote}
6   to withdraw official support for or discourage the use of
7   (something, such as a software product)
8   in favor of a newer or better alternative.
9 \end{quote}
10
11 The following software is deprecated for use with \PurdueThesisLogo.
12 Read the ‘‘Details’’
13 or ‘‘Used For’’
14 columns below for more information.
```

## I.1 Bibliography Software

---

Software Name	Details
Mendeley	If you don't currently use Mendeley and are thinking about using Mendeley just for your thesis I suggest that you do not do it. It may cause more problems than it solves. You can type the data needed for your bibliography directly into .bib files.

---

```
1
2
3 \section{Bibliography Software}
4
5 \noindent
6 \begin{tabularx}{\textwidth}{@{}lX@{}}
7   \toprule
8   \bf Software Name& \bf Details\\
9   \midrule
10  Mendeley&
11    If you don't currently use Mendeley
12    and are thinking about using Mendeley just for your thesis
13    I suggest that you do not do it.
14    It may cause more problems than it solves.
15    You can type the data needed for your bibliography
16    directly into .bib files.\\
17   \bottomrule
18 \end{tabularx}
```

## I.2 Packages

The `\usepackage{packagename}` command is used to load a package.

Do not use these packages—they are not compatible with PurdueThesis.

---

Package Name	Used For
babel	Translating “Table of Contents”, etc. to foreign languages. Reported by Danushka Menikkumbura. Send email to <code>latex@ecn.purdue.edu</code> if you need to typeset multiple languages in your thesis.
caption	Used to customize captions. Do not load this package, it is not compatible with PurdueThesis.
glossaries	Used to make glossaries. Do not load this package, it is not compatible with PurdueThesis. See the <code>front.tex</code> file for how to make a glossary.
glossary	For glossaries. This package is deprecated. Do not load this package. See <code>glossaries</code> .
subfig	For subfigures. This package is deprecated. Do not load this package. See page 81 for how to do subfigures.
subfigure	For subfigures. This package is deprecated. Do not load this package. See page 81 for how to do subfigures.

---

```

1
2
3 \section{Packages}
4
5 The
6 |\usepackage{|\Place{packagename}|}|
7 command is used to load a package.
8
9 Do not use these packages---they are not compatible with \PurdueThesisLogo.\\
10
11 \noindent
12 \begin{tabularx}{\textwidth}{@{}lX@{}}
13 \toprule
14 \bf Package Name& \bf Used For\\
15 \midrule
16 babel&
17     Translating ‘‘Table of Contents’’, etc\@. to foreign languages.
18     Reported by Danushka Menikkumbura.
19     Send email to \verb+latex@ecn.purdue.edu+ if you need to
20     typeset multiple languages in your thesis.\\
21 caption&
22     Used to customize captions.
23     Do not load this package, it is not compatible with \PurdueThesisLogo.\\
24 glossaries&
25     Used to make glossaries.
26     Do not load this package, it is not compatible with \PurdueThesisLogo.
27     See the \verb+front.tex+ file for how to make a glossary.\\
28 glossary&
29     For glossaries.
30     This package is deprecated.
31     Do not load this package.
32     See \verb+glossaries+.\\
33 subfig&
34     For subfigures.
35     This package is deprecated.
36     Do not load this package.
37     See page \pageref{pa:subfigures} for how to do subfigures.\\
38 subfigure&
39     For subfigures.

```



```
40     This package is deprecated.
41     Do not load this package.
42     See page \pageref{pa:subfigures} for how to do subfigures.\\
43     \bottomrule
44     \end{tabularx}
```

## J. FIGURES

```
1 \chapter{FIGURES}
```

The `h` specifier used in all the examples below tells  $\text{\LaTeX}$  to put the figure “here” instead of trying to find a good spot at the top or bottom of a page. Specifiers can be combined, for example, “`\begin{figure}[htbp!]`”.

```
1
2 The
3 \verb+h+
4 specifier used in all the examples below
5 tells \LaTeX\ to put the figure
6 ‘‘here’’
7 instead of trying
8 to find a good spot
9 at the top or bottom of a page.
10 Specifiers can be combined,
11 for example,
12 ‘‘\verb+\begin{figure}[htbp!]+’’.
```

The complete list of figure placement specifiers:

---

Specifier	Description
<code>b</code>	bottom of page
<code>h</code>	follow formatting rules and put here on page
<code>p</code>	on separate page of figures
<code>t</code>	top of page
<code>!</code>	try hard to put figure as early as possible
<code>H</code>	suspend formatting rules and put right here—requires <code>\usepackage{float}</code>

---

```
1
2 The complete list of figure placement specifiers:
3 \vspace*{6pt}
4 \begin{center}
5   \begin{tabular}{@{}l@{}}
6     \toprule
7     \bf Specifier& \bf Description\\
8     \midrule
9     \noalign{\vspace*{2pt}}
10    \tt b& bottom of page\\
11    \tt h& follow formatting rules and put here on page\\
12    \tt p& on separate page of figures\\
13    \tt t& top of page\\
14    \tt !& try hard to put figure as early as possible\\
15    \tt H& suspend formatting rules and put right here---requires \tt\char'134 usepackage\char'173 float\char'175\\
16    \bottomrule
17   \end{tabular}
18 \end{center}
19 \index{figure!placement specifiers (\verb+b+, \verb+h+, \verb+p+, \verb+t+, {\tt\char'041}, \verb+H+)}
20 \index{\verb+\begin{tabular}+}
```

This is the first paragraph. This is the first paragraph. This is the first paragraph. This is the first paragraph. This is the first paragraph.

This is the figure.

**Figure J.1.** Allocation to Common Edge for  $p(x_i) = 1 - e^{-x_i z}$

```
1
2 % MyRepeat is defined in MyRepeat.sty.
3 \MyRepeat{This is the first paragraph. }{5}

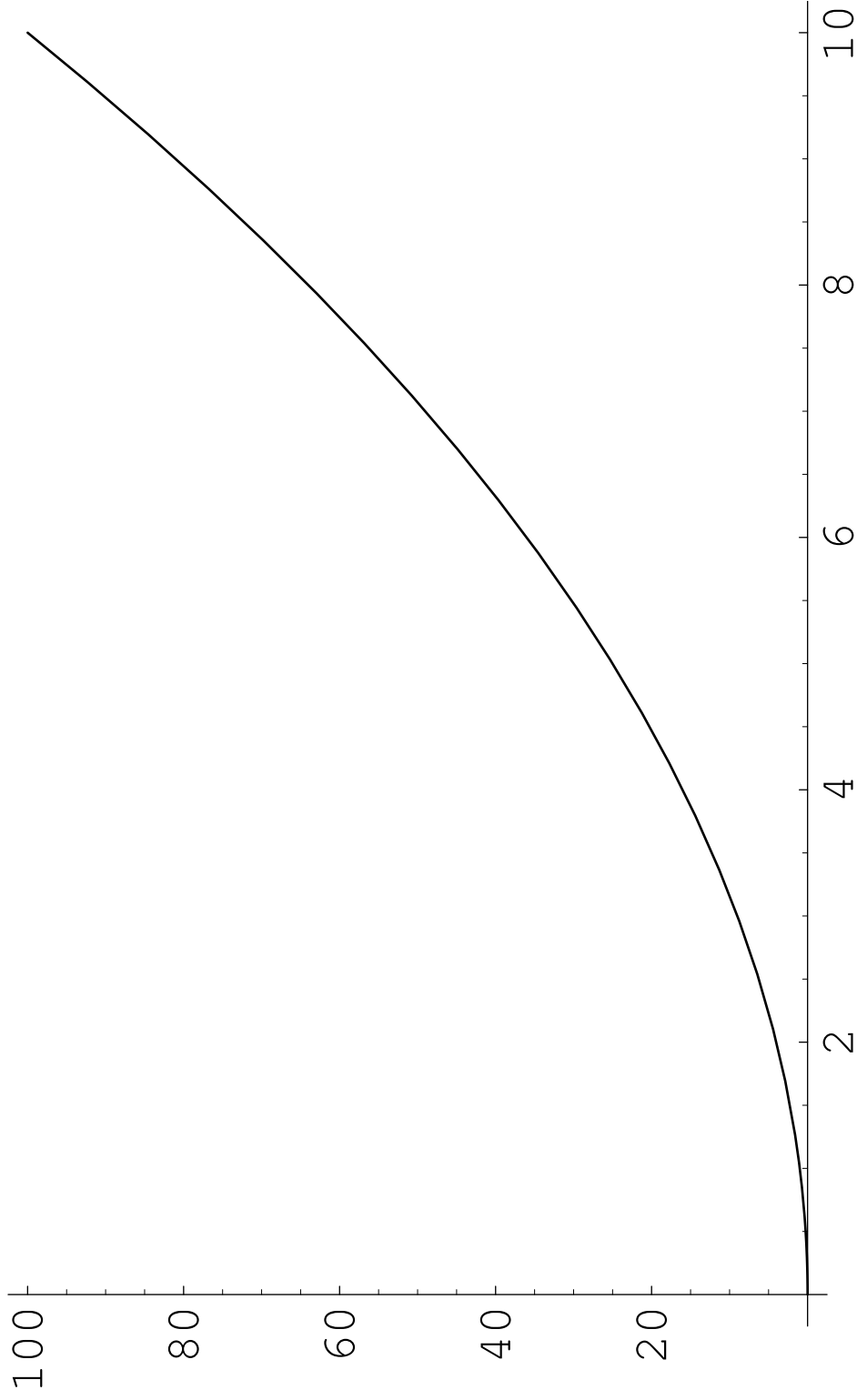
1
2 \begin{figure}[h]
3   This is the figure.
4   \caption{%
5     Allocation to Common Edge for
6     \((p(x_i) = 1-e^{-x_i z})\)% \frac{-x_i}{z}\)}%
7   }
8 \end{figure}

1
2 \begin{sidewaysfigure}[ht]
3   \setbox0=\hbox{%
4     \noindent
5     This is the second figure in this appendix.
6     This is the second figure in this appendix.
7     This is%
8   }
9   \dimen0=\wd0
10  \hbox to \textwidth{\hss\box0\hss}
11  \textwidth=\dimen0
12  \advance\textwidth by 1truein
13  \caption{%
14    This is the caption for the second figure.
15    This is the caption for the second figure.
16    This is the caption for the second figure.%
17  }
18 \end{sidewaysfigure}
```

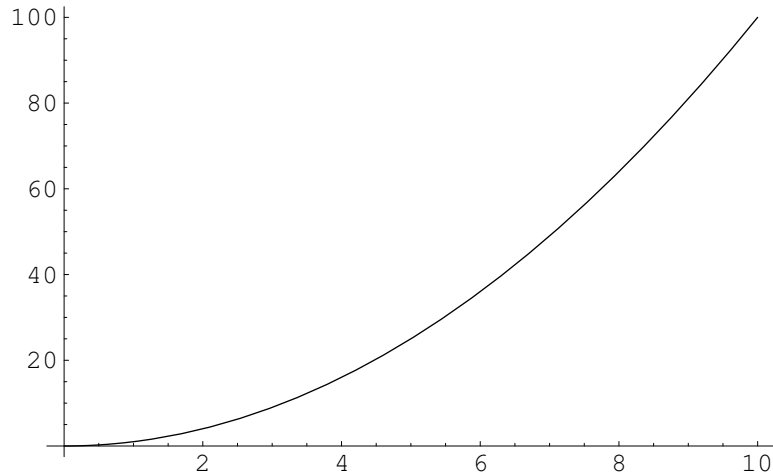
This is the second figure in this appendix. This is the second figure in this appendix. This is

**Figure J.2.** This is the caption for the second figure. This is the caption for the second figure. This is the caption for the second figure.

```
1
2 \begin{sidewaysfigure}[ht]
3   \setbox0=\hbox{\noindent \includegraphics[width=8truein]{gr-plot.pdf}}
4   \dimen0=\wd0
5   \hbox to \textwidth{\hss\box0\hss}
6   \textwidth=\dimen0
7   \advance\textwidth by 1truein
8   \caption{
9     This is the caption for the third figure.
10    This is the caption for the third figure.
11    This is the caption for the third figure.%
12  }
13 \end{sidewaysfigure}
```



**Figure J.3.** This is the caption for the third figure. This is the caption for the third figure. This is the caption for the third figure.



**Figure J.4.** By default figures are not centered. This is a long caption to demonstrate that captions are single spaced. This is a long caption to demonstrate that captions are single spaced.

```

1
2 \begin{figure}[ht]
3   \includegraphics{gr-plot.pdf}
4   \caption
5   {%
6     By default figures are not centered.
7     This is a long caption to demonstrate that captions are single spaced.
8     This is a long caption to demonstrate that captions are single spaced.%
9   }
10  \label{fi:not-centered}
11 \end{figure}

```

This is the second paragraph. This is the second paragraph. This is the second paragraph. This is the second paragraph. This is the second paragraph. This is the second paragraph. This is the second paragraph. This is the second paragraph.

```

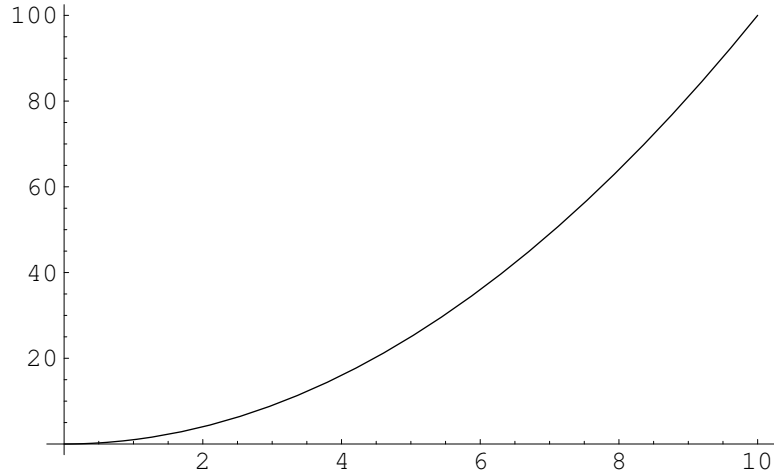
1
2 \MyRepeat{This is the second paragraph. }{10}

```

```

1
2 \begin{figure}[ht]
3   \centering
4   \includegraphics{gr-plot.pdf}
5   \caption{Use {\tt \char'134centering\} to center figures.}
6   \label{fi:centered}
7 \end{figure}

```



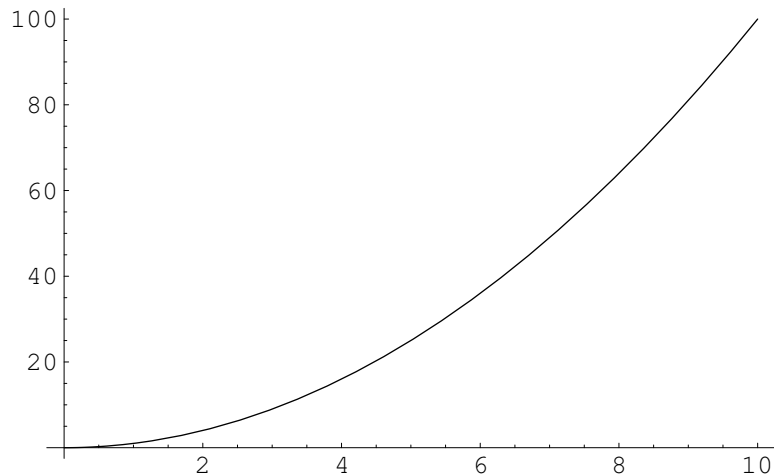
**Figure J.5.** Use `\centering` to center figures.

This is the third paragraph. This is the third paragraph.

```

1
2 \MyRepeat{This is the third paragraph. }{15}

```



**Figure J.6.** This is another figure.

```

1
2 \begin{figure}[ht]

```



```

3 \centering
4 \includegraphics{gr-plot.pdf}
5 \caption{This is another figure.}
6 \label{fi:another}
7 \end{figure}

```

This is the fourth paragraph. This is the fourth paragraph. This is the fourth paragraph. This is the fourth paragraph. This is the fourth paragraph. This is the fourth paragraph. This is the fourth paragraph. This is the fourth paragraph. This is the fourth paragraph.

```

1
2 \MyRepeat{This is the fourth paragraph. }{10}

```

**First subfigure.**

(a) First subcaption.

**Second subfigure.**

(b) Second subcaption.

**Figure J.7.** This figure has two subfigures arranged horizontally.

```

1
2 % See pages 4--5 of
3 % http://mirrors.ibiblio.org/CTAN/macros/latex/contrib/caption/subcaption.pdf
4 % for how to use \subcaptionbox.
5 \begin{figure}[ht]
6 % Center the entire figure (containing the two subfigures).
7 \centering
8 % The \subcaptionbox for the first subfigure.
9 \subcaptionbox
10 % The first subcaption with a \label.
11 % Use \ref{sf:two-parts-a} to print the subcaption number.
12 {First subcaption.\label{sf:two-parts-a}}%
13 % The first subfigure is this wide.
14 [2in]%
15 % This is the first subfigure.
16 % You'll usually use an \includegraphics{filename}
17 % inside the braces on the next line.
18 {\bfseries First subfigure.}%
19 % Put 0.5 inches of blank space between the subfigures.
20 \hskip 0.5truein
21 \subcaptionbox
22 {Second subcaption.\label{sf:two-parts-b}}%
23 [2in]%
24 {\bfseries Second subfigure.}%
25 % The caption for the entire figure (containing two subfigures).
26 \caption{This figure has two subfigures arranged horizontally.}
27 % The label for the entire figure.
28 \label{fi:two-horizontal-parts}
29 \end{figure}
30 \ix{figure!subfigures!{\(\text{1 row} \times \text{2 columns}\)}}

```

This is the fifth paragraph. This is the fifth paragraph. This is the fifth paragraph. This is the fifth paragraph. This is the fifth paragraph. This is the fifth paragraph. This is the fifth paragraph. This is the fifth paragraph. This is the fifth paragraph.

### First subfigure.

(a) First subcaption.

### Second subfigure.

(b) Second subcaption.

**Figure J.8.** This figure has two subfigures arranged vertically.

```
1
2 \MyRepeat{This is the fifth paragraph. }{10}

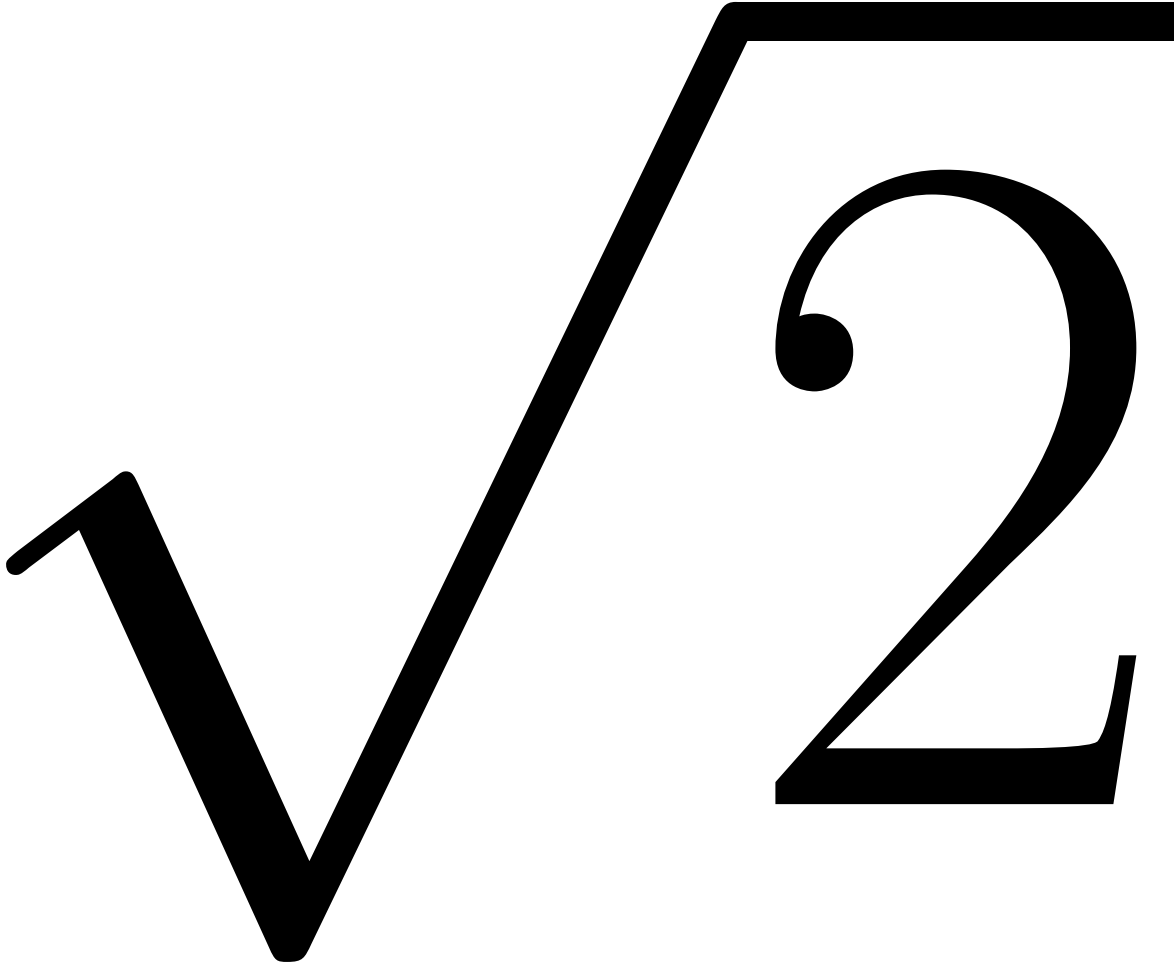
1
2 % See pages 4--5 of
3 % http://mirrors.ibiblio.org/CTAN/macros/latex/contrib/caption/subcaption.pdf
4 % for how to use \subcaptionbox.
5 \begin{figure}[ht]
6 % Center the entire figure (containing the two subfigures).
7 \centering
8 % The \subcaptionbox for the first subfigure.
9 \vbox{\subcaptionbox % use \vbox to stack subcaption boxes vertically
10 % The first subcaption with a \label.
11 % Use \ref{sf:two-vertical-parts-a} to print the subcaption number.
12 {First subcaption.\label{sf:two-vertical-parts-a}}
13 [2in]%
14 {\bfseries First subfigure.}}%
15 % Put \baselineskip blank space between the subfigures.
16 \vspace*{\baselineskip}
17 % The \subcaptionbox for the second subfigure.
18 \vbox{\subcaptionbox % use \vbox to stack subcaption boxes vertically
19 {Second subcaption.\label{sf:two-vertical-parts-b}}
20 [2in]%
21 {\bfseries Second subfigure.}}%
22 \caption{This figure has two subfigures arranged vertically.}
23 \label{fi:two-vertical-parts}
24 \end{figure}
25 \ix{figure!subfigures!\(\text{2 rows} \times \text{1 column}\)}
```

This is the sixth paragraph. This is the sixth paragraph. This is the sixth paragraph. This is the sixth paragraph. This is the sixth paragraph. This is the sixth paragraph. This is the sixth paragraph. This is the sixth paragraph.

```
1
2 \MyRepeat{This is the sixth paragraph. }{10}

1
2 % See pages 4--5 of
3 % http://mirrors.ibiblio.org/CTAN/macros/latex/contrib/caption/subcaption.pdf
4 % for how to use \subcaptionbox.
5 \begin{figure}[ht]
6 \centering
7 \subcaptionbox
```





**Figure J.10.** A big “ $\sqrt{2}$ ”. L<sup>A</sup>T<sub>E</sub>X can make output big enough for T-shirts or posters. Square roots are printed with space before them, I put some negative horizontal space before this one to center it.

```
1
2 \newpage
3
4 \begin{figure}[ht]
5   \centering
6   % Use a 5" font.
7   {\fontsize{5in}{5in}\selectfont{\hspace*{-0.07em}\sqrt{2}}}
8   \caption{%
9     A big ‘‘\(\sqrt{2}\)’’.
10    \LaTeX\ can make output big enough for T-shirts or posters.
11    Square roots are printed with space before them,
12    I put some negative horizontal space before this one to center it.%
13  }
14 \end{figure}
15 \ix{figure!\(\sqrt{2}\)}
```

This is the figure.

**Figure J.11.** Allocation to Common Edge for  $p(x_i) = 1 - e^{-x_i z}$

The remainder of this file tests having lots of figures. There are 20 figures in this test.



**Figure J.12.** Test figure 1 of 20.



**Figure J.13.** Test figure 2 of 20.



**Figure J.14.** Test figure 3 of 20.



**Figure J.15.** Test figure 4 of 20.



**Figure J.16.** Test figure 5 of 20.



**Figure J.17.** Test figure 6 of 20.

```
1
2 \newpage
3
4 The remainder of this file tests having lots of figures.
5 There are 20 figures in this test.
6
7 \begin{figure}[ht]
8   \centering
9   \includegraphics[scale=0.5]{gr-metapost-tally-01.pdf}
10  \caption{Test figure 1 of 20.}
11  \label{fi:1of20}
12 \end{figure}
13
14 \begin{figure}[ht]
15   \centering
```



Figure J.18. Test figure 7 of 20.



Figure J.19. Test figure 8 of 20.



Figure J.20. Test figure 9 of 20.



Figure J.21. Test figure 10 of 20.



Figure J.22. Test figure 11 of 20.



Figure J.23. Test figure 12 of 20.



Figure J.24. Test figure 13 of 20.

```

16 \includegraphics[scale=0.5]{gr-metapost-tally-02.pdf}
17 \caption{Test figure 2 of 20.}
18 \label{fi:2of20}
19 \end{figure}
20
21 \begin{figure}[ht]
22 \centering
23 \includegraphics[scale=0.5]{gr-metapost-tally-03.pdf}
24 \caption{Test figure 3 of 20.}
25 \label{fi:3of20}
26 \end{figure}
27
28 \begin{figure}[ht]
29 \centering
30 \includegraphics[scale=0.5]{gr-metapost-tally-04.pdf}
31 \caption{Test figure 4 of 20.}
32 \label{fi:4of20}
33 \end{figure}

```



Figure J.25. Test figure 14 of 20.

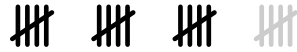


Figure J.26. Test figure 15 of 20.



Figure J.27. Test figure 16 of 20.



Figure J.28. Test figure 17 of 20.

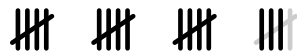


Figure J.29. Test figure 18 of 20.

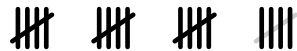


Figure J.30. Test figure 19 of 20.



Figure J.31. Test figure 20 of 20.

```
34
35 \begin{figure}[ht]
36   \centering
37   \includegraphics[scale=0.5]{gr-metapost-tally-05.pdf}
38   \caption{Test figure 5 of 20.}
39   \label{fi:5of20}
40 \end{figure}
41
42 \begin{figure}[ht]
43   \centering
44   \includegraphics[scale=0.5]{gr-metapost-tally-06.pdf}
45   \caption{Test figure 6 of 20.}
46   \label{fi:6of20}
47 \end{figure}
48
49 \begin{figure}[ht]
50   \centering
51   \includegraphics[scale=0.5]{gr-metapost-tally-07.pdf}
```



```

52 \caption{Test figure 7 of 20.}
53 \label{fi:7of20centered7}
54 \end{figure}
55
56 \begin{figure}[ht]
57 \centering
58 \includegraphics[scale=0.5]{gr-metapost-tally-08.pdf}
59 \caption{Test figure 8 of 20.}
60 \label{fi:8of20}
61 \end{figure}
62
63 \begin{figure}[ht]
64 \centering
65 \includegraphics[scale=0.5]{gr-metapost-tally-09.pdf}
66 \caption{Test figure 9 of 20.}
67 \label{fi:9of20}
68 \end{figure}
69
70 \begin{figure}[ht]
71 \centering
72 \includegraphics[scale=0.5]{gr-metapost-tally-10.pdf}
73 \caption{Test figure 10 of 20.}
74 \label{fi:10of20}
75 \end{figure}
76
77 \begin{figure}[ht]
78 \centering
79 \includegraphics[scale=0.5]{gr-metapost-tally-11.pdf}
80 \caption{Test figure 11 of 20.}
81 \label{fi:11of20}
82 \end{figure}
83
84 \begin{figure}[ht]
85 \centering
86 \includegraphics[scale=0.5]{gr-metapost-tally-12.pdf}
87 \caption{Test figure 12 of 20.}
88 \label{fi:12of20}
89 \end{figure}
90
91 \begin{figure}[ht]
92 \centering
93 \includegraphics[scale=0.5]{gr-metapost-tally-13.pdf}
94 \caption{Test figure 13 of 20.}
95 \label{fi:13of20}
96 \end{figure}
97
98 \begin{figure}[ht]
99 \centering
100 \includegraphics[scale=0.5]{gr-metapost-tally-14.pdf}
101 \caption{Test figure 14 of 20.}
102 \label{fi:14of20}
103 \end{figure}
104
105 \begin{figure}[ht]
106 \centering
107 \includegraphics[scale=0.5]{gr-metapost-tally-15.pdf}
108 \caption{Test figure 15 of 20.}
109 \label{fi:15of20}
110 \end{figure}
111
112 \begin{figure}[ht]
113 \centering
114 \includegraphics[scale=0.5]{gr-metapost-tally-16.pdf}
115 \caption{Test figure 16 of 20.}

```

```
116 \label{fi:16of20}
117 \end{figure}
118
119 \begin{figure}[ht]
120 \centering
121 \includegraphics[scale=0.5]{gr-metapost-tally-17.pdf}
122 \caption{Test figure 17 of 20.}
123 \label{fi:17of20}
124 \end{figure}
125
126 \begin{figure}[ht]
127 \centering
128 \includegraphics[scale=0.5]{gr-metapost-tally-18.pdf}
129 \caption{Test figure 18 of 20.}
130 \label{fi:18of20}
131 \end{figure}
132
133 \begin{figure}[ht]
134 \centering
135 \includegraphics[scale=0.5]{gr-metapost-tally-19.pdf}
136 \caption{Test figure 19 of 20.}
137 \label{fi:19of20}
138 \end{figure}
139
140 \begin{figure}[ht]
141 \centering
142 \includegraphics[scale=0.5]{gr-metapost-tally-20.pdf}
143 \caption{Test figure 20 of 20.}
144 \label{fi:20of20}
145 \end{figure}
```

## K. FREQUENTLY ASKED QUESTIONS

This appendix lists all frequently asked questions. Each frequently asked question is assigned a number when I learn of it. FAQ numbers are 1, 2, . . . . I started keeping track of frequently asked questions in this fashion on March 1, 2022.

Description	Color
done or waiting on someone else	black
high priority or easy to do	red
low priority	blue
not prioritized yet	gray

See the `ap-frequently-asked-questions.tex` file for the Lua $\LaTeX$  input for this appendix.

### K.1 These questions need to be answered

### K.2 These questions are waiting on a reply from someone other than Mark Senn

### K.3 These questions have been answered

The subsection headings below are what part of the document the question is about.

#### Everywhere

**FAQ 1.** The  $\LaTeX$  input

```
$a | b$ (Mark Senn recommends using \(a | b\) instead)
```

gives

```
! LaTeX Error: Command \ttfamily invalid in math mode.
```

Reported by Negin Karisani.

**A:** In `thesis.tex`, change

```
\DefineShortVerb{\|} % so "|verbatim|" will be verbatim
```

to

```
% \DefineShortVerb{\|} % so "|verbatim|" will be verbatim
```

**FAQ 5.** When using Overleaf on Firefox I get a gratuitous ‘□’ in the upper-left corner of each page.

**A:** Resetting Firefox (warning: this resets lots of stuff) using the following steps worked for me:

1. Select `Help` `»` `Troubleshoot Mode`.
2. Click `Restart`.
3. Click `Refresh Firefox`.

4. Click `Refresh Firefox`.
5. Click `Let's Go`.

## Table of Contents

**FAQ 2.** I want text instead of page number to be the link in the table of contents. Asked by Danushka Menikkumbura on 2022-03-11.

**A:** In `PurdueThesis.cls` change `linktoc = page` to `linktoc = section`. I do not recommend doing this because

- you'll need to put this change in new `PurdueThesis.cls` files in the future
- people are used to using page numbers instead of chapter/section/etc. titles for where they start

## Chapters

**FAQ 6.** Sections are numbered 2.1, 2.2, 2.3, 2.1 using `\chapterappendix`. They should be numbered 2.1, 2.2, 2.3, 2.A. How do I fix this? Asked by Ryan Hastings on 2024-10-28.

**A:** Change

```
\chapterappendix
```

to

```
\chapterappendix
```

```
\renewcommand{\thesection}{\thechapter.\AlphAlph{\value{section}}}
```

This was fixed in the new `PurdueThesis` software that was put on Overleaf around October 25, 2024. It contains lots of changes but I suggest you do not update to it if you plan to graduate in December 2024—you'd need to read and make some updates to your `PurdueThesis.cls`, `thesis.tex`, and `front.tex` files.

## References

**FAQ 4.** I have an `@online{...reference with no date = {...}}` and `'()`' gets printed in the references around where the date would go. How can I prevent the `'()`' from getting printed. Asked by Pratith Narasimha Shenai on 2023-07-15. **A:** Use `@online[*]{...}` instead of `@online{...}`. I don't know why this works.

## Appendix

**FAQ 3.** Label Appendix/Appendices with APPENDIX. Asked by Panos Manganaris on 2023-06-16. **A:** Mark Jaeger, former Manager of the Thesis and Dissertation Office, wrote and said that the most important thing in a thesis was 'consistency, consistency, consistency'.

For consistency,

- Chapters aren't labeled with 'CHAPTER' so Appendix/Appendices aren't labeled with 'APPENDIX'.
- Chapters are listed as 1, 2, ... and appendices are listed as A, B, ... in the Table of Contents.

Contemporary usage is to not label chapters or appendices see MIT theses [60, 61], Stanford theses [62, 63], and T<sub>E</sub>X/L<sup>A</sup>T<sub>E</sub>X documentation [30, 52, 64].

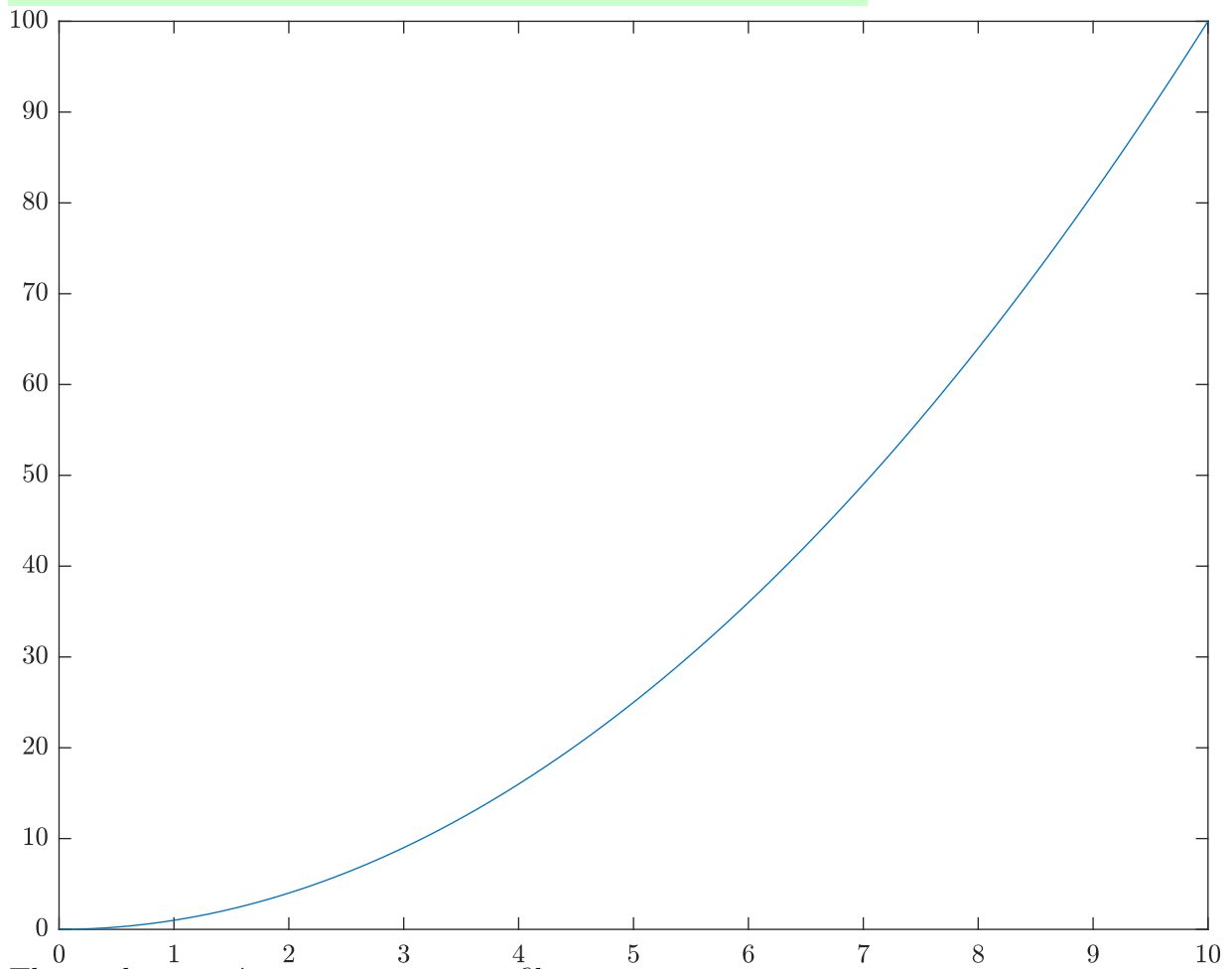
## L. GRAPHICS

There are many ways to make graphics for L<sup>A</sup>T<sub>E</sub>X. I like to use a system that uses L<sup>A</sup>T<sub>E</sub>X fonts so the appearance of the output is professional.

```
1 \chapter{GRAPHICS}
2
3 There are many ways to make graphics for \LaTeX.
4 I like to use a system that uses \LaTeX fonts
5 so the appearance of the output is professional.
```

### L.1 MATLAB programming language

By default, MATLAB supports a subset of TeX markup [65].



```
1 % gr_matlab.m    2021-11-11    Mark Senn <mark@purdue.edu>
2
3 % On Linux, I typed
4 %     lm matlab
5 %     matlab -nodesktop -nosplash -r gr_matlab
6 % to run this program.
7
8 % See
```

```

9 % https://www.mathworks.com/matlabcentral/answers/346436-how-to-use-latex-interpreter-for-xticklabels
10 % Do axis labels using LaTeX.
11 set(groot, 'defaultAxesTickLabelInterpreter', 'latex');
12 % Do legends using LaTeX.
13 set(groot, 'defaultLegendInterpreter', 'latex');
14 % Do text using LaTeX.
15 set(groot, 'defaulttextinterpreter', 'latex');
16
17 x = linspace(0,10,100);
18 y = x .^ 2;
19 plot(x, y);
20 saveas(gcf, '../graphics/gr-matlab.pdf');
21
22 % The following line worked for me on Linux.
23 !pdfcrop ../graphics/gr-matlab.pdf ../graphics/gr-matlab.pdf;
24
25 exit;

```

I typed, on Linux, `matlab -nodisplay -nodesktop -nosplash -r gr_matlab` in the `misc` subdirectory to make the `graphics/gr-matlab.pdf` output file.

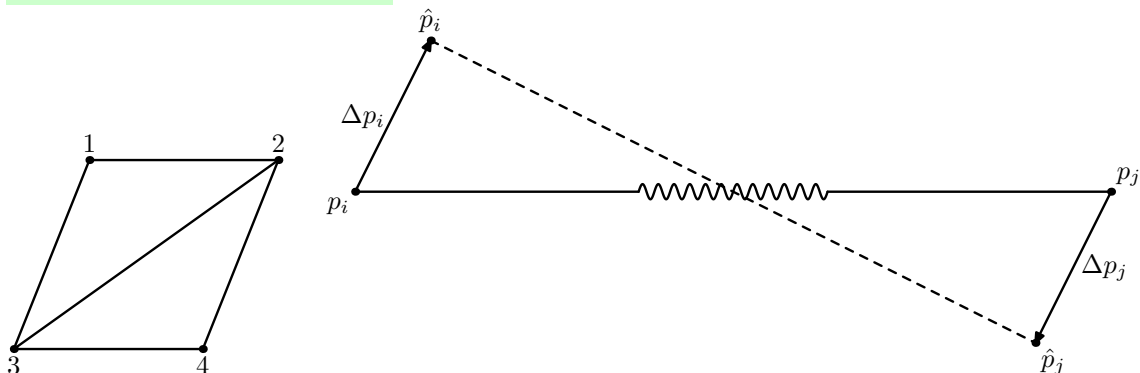
```

1
2 \section{MATLAB programming language}
3 \ix{MATLAB programming language}
4
5 \def\gray#1{\colorbox{gray!15}{#1}}
6 \def\lightred#1{\colorbox{red!15}{#1}}
7 \def\lightgreen#1{\colorbox{green!20}{#1}}
8 \lightgreen{
9   By default,
10  MATLAB supports a subset of TeX markup
11  \cite{mathworks-help-center-text-properties}.
12 }
13
14 \includegraphics{gr-matlab.pdf}
15
16 This is the |misc/gr_matlab.m| input file:
17 \MyI{misc/gr_matlab.m}
18
19 I typed, on Linux,
20 \Shell{matlab -nodisplay -nodesktop -nosplash -r gr\_matlab}
21 in the |misc| subdirectory
22 to make the |graphics/gr-matlab.pdf| output file.

```

## L.2 METAPOST programming language

MetaPost uses L<sup>A</sup>T<sub>E</sub>X fonts.



This is the misc/gr-metapost-kim.mp input file:

```

1  % gr-metapost.mp 2021-11-16 Mark Senn https://bit.ly/markseenn
2  %
3  % Thanks to Yanghyun Kim for asking how to do this figure.
4  %
5
6  prologues := 3; % make .eps files with embedded fonts
7
8  outputtemplate := "%j-%c.mps"; % make output files gr-metapost-1.mps and gr-metapost-2.mps
9
10 beginfig(1);
11   pickup pencircle scaled 1pt; % line width
12
13   u := 0.5cm; % unit size
14
15   deltax := 5u;
16   deltay := 5u;
17   xoff := 2u;
18
19   pair ll, lr, ul, ur;
20   ll := (0, 0); % lower left point
21   lr := ll + (deltax, 0); % lower right point
22   ul := ll + (xoff, deltay); % upper left point
23   ur := ul + (deltax, 0); % upper right point
24
25   draw ll--lr--ur--ul--ll;
26   draw ll--ur;
27
28   dotlabel.top(btex 1 etex, ul); % top label
29   dotlabel.top(btex 2 etex, ur); % top label
30   dotlabel.bot(btex 3 etex, ll); % bottom label
31   dotlabel.bot(btex 4 etex, lr); % bottom label
32 endfig;
33
34 beginfig(2);
35   pickup pencircle scaled 1pt; % line width
36
37   u := 2cm; % unit size
38
39   deltax := 5u;
40   deltay := 1u;
41   xoff := 0.5u;
42
43   pair ll, lr, ul, ur;
44   ll := (0, 0); % lower left point
45   ur := ll + (deltax, 0); % upper right point
46   ul := ll + (xoff, deltay); % upper left point
47   lr := ur + (-xoff, -deltay); % lower right point
48
49   dotlabel.llft(btex $p_i$ etex, ll); % lower left label
50   label.lft( btex $\Delta p_i$ etex, 1/2[ll,ul]); % left label
51   dotlabel.top( btex ${\hat p}_i$ etex, ul); % upper left label
52
53   dotlabel.lrt(btex ${\hat p}_j$ etex, lr); % lower right label
54   label.rt( btex $\Delta p_j$ etex, 1/2[lr,ur]); % right label
55   dotlabel.urt(btex $p_j$ etex, ur); % upper right label
56
57   drawarrow ll--ul;
58   drawarrow ur--lr;
59   draw ul--lr dashed evenly;
60   draw ll--3/8[ll,ur];
61   draw 3/8[ll,ur]{up}
62   for i = 0 upto 360:

```



```

63         ..3/8[ll,ur] + ((i/360)*(deltax/4), (u/20)*sind(12i))
64     endfor;
65     draw 5/8[ll,ur]--ur;
66 endfig;
67
68 end.

```

I typed, on Linux,

```

mpost gr-metapost-kim
epstopdf gr-metapost-kim-1.mps; epstopdf gr-metapost-kim-2.mps
mv -i gr-metapost-kim-1.pdf gr-metapost-kim-2.pdf ../graphics

```

to run MetaPost and make `gr-metapost-kim-1.pdf` and `gr-metapost-kim-2.pdf`, and move them to the `graphics` subfolder.

```

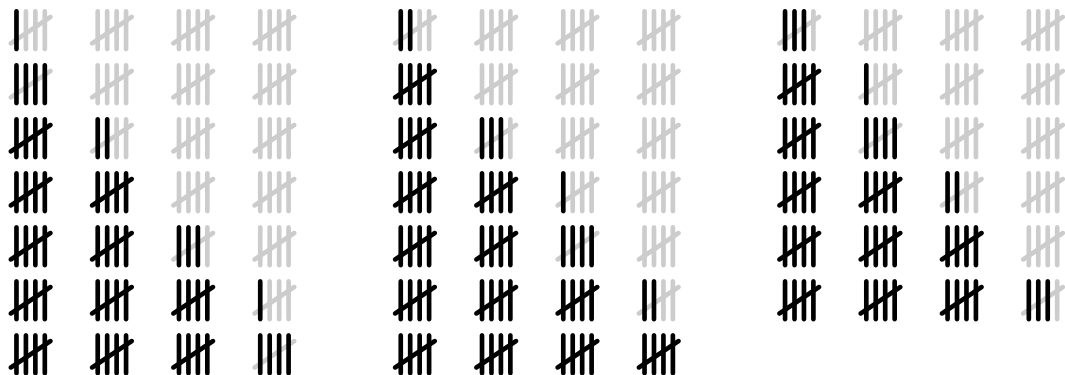
1
2 \section{\protect\METAPOSTLogo\ programming language}
3 \index{METAPOST@METAPOSTLogo}
4 \todoindex{\METAPOSTLogo}
5
6 \lightgreen{\MetaPostLogo\ uses \LaTeX\ fonts.}
7 \todoindex{\MetaPostLogo}
8
9 \includegraphics{gr-metapost-kim-1.pdf}
10 \hspace*{0.1truein}
11 \includegraphics{gr-metapost-kim-2.pdf}
12
13 This is the |misc/gr-metapost-kim.mp| input file:
14 \MyI{misc/gr-metapost-kim.mp}
15
16 I typed, on Linux,\
17 \hspace*{3\parindent}\Shell{mpost gr-metapost-kim}\
18 \hspace*{3\parindent}\Shell{epstopdf gr-metapost-kim-1.mps; epstopdf gr-metapost-kim-2.mps}\
19 \hspace*{3\parindent}\Shell{mv -i gr-metapost-kim-1.pdf gr-metapost-kim-2.pdf ../graphics}\
20 to run MetaPost and make |gr-metapost-kim-1.pdf|
21 and |gr-metapost-kim-2.pdf|,
22 and move them to the graphics subfolder.

```

## L.2.1 Tally example

Whenever I use files with numbers in them I like to put leading zeros in the names so they will be listed in order in the directory.

These 20 graphics (`gr-metapost-tally-01.pdf` through `gr-metapost-tally-20.pdf`)



were produced by

```

1 %
2 % gr-metapost-tally.mp 2022-01-14 Mark Senn https://bit.ly/markseenn
3 %
4 % Make 20 .pdf files for the tally mark representations for 1 to 20.
5 %
6 % Whenever I use files with numbers in them I like to put leading zeros
7 % in the names so they will be listed in order in the directory.
8 %
9 % Do these commands:
10 % mpost gr-metapost-tally
11 % epspdf gr-metapost-tally-1.mps; mv gr-metapost-tally-1.pdf gr-metapost-tally-01.pdf
12 % epspdf gr-metapost-tally-2.mps; mv gr-metapost-tally-2.pdf gr-metapost-tally-02.pdf
13 % ...
14 % epspdf gr-metapost-tally-9.mps; mv gr-metapost-tally-9.pdf gr-metapost-tally-09.pdf
15 % epspdf gr-metapost-tally-20.mps; mv gr-metapost-tally-20.pdf gr-metapost-tally-20.pdf
16 %
17 % If you use bash you can do
18 % for i in $(seq 1 20); \
19 % do epspdf gr-tally- $i$ .mps ; printf -v var "%02d" " $i$ "; mv gr-tally- $i$ .pdf gr-tally- $\$var$ .pdf; \
20 % done
21 % to do all the lines that start with epspdf.
22 %
23
24 prologues := 3;
25 outputtemplate := "gr-%j-%c.mps";
26 outputformat := "eps";
27
28 % Define dimensions.
29 adjust = 0.15cm; % x and y adjustment
30 dx = 0.25cm; % delta x
31 h = 1cm; % tally height
32 s = 1cm; % spacing between groups of tally marks
33
34 % Define number of tally marks.
35 n = 20; % number of marks
36
37 % Compute the tally mark paths.
38 path p[];
39 x := 0; xstart := x;
40 for i = 1 upto n:
41 if (i mod 5 = 1):
42 p[i] = ((x,0)--(x,h)); x := x + dx;
43 fi;
44 if (i mod 5 = 2):
45 p[i] = ((x,0)--(x,h)); x := x + dx;
46 fi;
47 if (i mod 5 = 3):
48 p[i] = ((x,0)--(x,h)); x := x + dx;
49 fi;
50 if (i mod 5 = 4):
51 p[i] = ((x,0)--(x,h));
52 fi;
53 if (i mod 5 = 0):
54 p[i] = ((xstart-adjust,adjust)--(x+adjust,h-adjust));
55 x := x + dx + adjust + s; xstart := x;
56 fi;
57 endfor;
58 show p[1];
59
60 %
61 % Write the tally-*.mps files
62 %
63
64 for i = 1 upto n:

```

```

65
66     beginfig(i);
67
68         % Define pen---this must go between beginfig and endfig.
69         pen mypen;
70         mypen = pencircle scaled 3.5;
71         pickup mypen;
72
73         % Draw gray tally marks.
74         for j = i+1 upto n:
75             draw p[j] withcolor 0.8white;
76         endfor;
77
78         % Draw black tally marks.
79         % Do this last so the dark tally marks
80         % will be on top of the light tally marks.
81         for j = 1 upto i:
82             draw p[j] withcolor black;
83         endfor;
84
85     endfig;
86
87 endfor;
88
89 end.

1
2 \subsection{Tally example}
3 \label{ss:tally-example}
4
5 Whenever I use files with numbers in them I like to put leading zeros
6 in the names so they will be listed in order in the directory.
7
8 These 20 graphics (|gr-metapost-tally-01.pdf| through |gr-metapost-tally-20.pdf|)
9
10 \vspace*{6pt}
11
12 {%
13     % Let * represent zero or more spaces!
14     % Method 1: \def\g#1{ requires using \g*{10} for 10.
15     %           Two shifted characters, { and } are needed.
16     % Method 2: \def\g#1/{ requires using \g*10/ for 10.
17     %           One unshifted character, / is needed.
18     \def\g#1/{\includegraphics[scale=0.5]{gr-metapost-tally-#1.pdf}}%
19
20     % Note that tabular* instead of tabular is used below.
21     % The {\textwidth} makes the total width of the table the width
22     % of the printed area of the page.
23     % The @{\kern2\parindent} puts blank space the width of two
24     % paragraph indents before the first column.
25     % The @{\extracolsep{\fill}} adds \fill space between all subsequent
26     % columns.
27     % The lll left justifies the next three columns.
28     % after the column.
29     % The @{\kern2\parindent} puts blank space the width of two
30     % paragraph indents before the first column.
31     \begin{tabular*}{\textwidth}{@{\kern2\parindent}@{\extracolsep{\fill}}lll@{\kern2\parindent}}%
32         \g 01/& \g 02/& \g 03/\
33         \g 04/& \g 05/& \g 06/\
34         \g 07/& \g 08/& \g 09/\
35         \g 10/& \g 11/& \g 12/\
36         \g 13/& \g 14/& \g 15/\
37         \g 16/& \g 17/& \g 18/\
38         \g 19/& \g 20/\

```

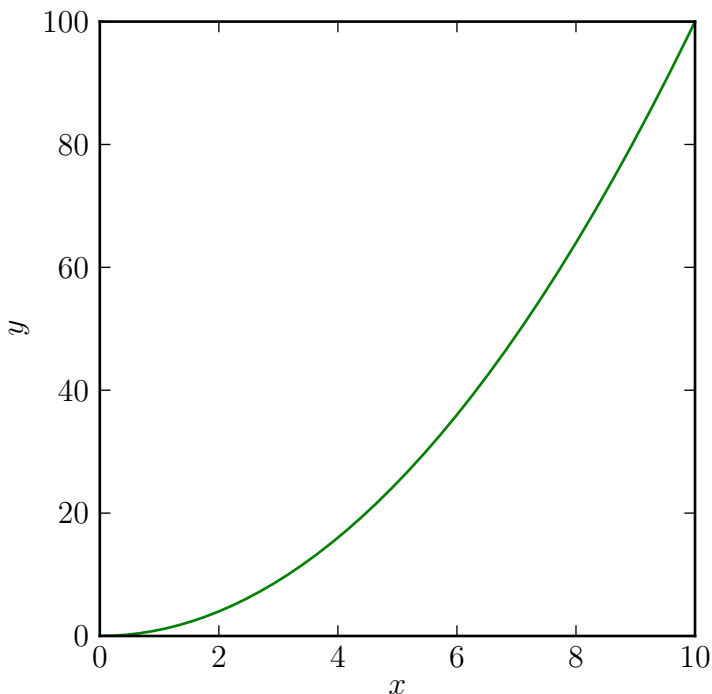
```

39 \end{tabular*}%
40 }
41 \noindent were produced by
42
43 \MyI{misc/gr-metapost-tally.mp}
44

```

### L.3 Python programming language

Python can be set up to use L<sup>A</sup>T<sub>E</sub>X fonts.



This is the misc/gr-python2.py input file:

```

1  #!/bin/python2
2
3  # gr-python2.py    2023-08-31    Mark Senn <mark@purdue.edu>
4
5  # On Linux, I typed
6  #    ./gr-python2.py
7  # to run this program.
8
9  import matplotlib as mpl
10
11 # From https://matplotlib.org/stable/gallery/text_labels_and_annotations/tex_demo.html
12 # You can use TeX to render all of your Matplotlib text by setting
13 # rcParams["text.usetex"] (default: False) to True. This requires
14 # that you have TeX and the other dependencies described in the
15 # Text rendering With LaTeX tutorial properly installed on your
16 # system. Matplotlib caches processed TeX expressions, so that
17 # only the first occurrence of an expression triggers a TeX
18 # compilation. Later occurrences reuse the rendered image from the
19 # cache and are thus faster.
20 mpl.rcParams['text.usetex'] = True

```

```

21
22 # From
23 # https://stackoverflow.com/questions/2801882/generating-a-png-with-matplotlib-when-display-is-undefined
24 # # Force matplotlib to not use any Xwindows backend.
25 # matplotlib.use('Agg')
26 mpl.use('Agg')
27
28 import matplotlib.pyplot as plt
29
30 plt.figure(figsize=(4,4))
31
32 import numpy as np
33
34 x = [ ]
35 y = [ ]
36 for i in range(0,1001):
37     x.append(i / 100.0)
38     y.append((i/100.0) ** 2)
39
40 # Normally, there is extra space to the left, right, top, and bottom
41 # of plotted data in a graph. This gets rid of that space.
42 plt.autoscale(enable=None, tight=True)
43
44 plt.plot(x, y, 'g')
45
46 plt.xlabel('$x$')
47 plt.ylabel('$y$')
48
49 plt.savefig('../graphics/gr-python2.pdf')

```

I typed, on Linux, `./gr-python2.py` in the `misc` subdirectory to make the `graphics/gr-python2.pdf` output file.

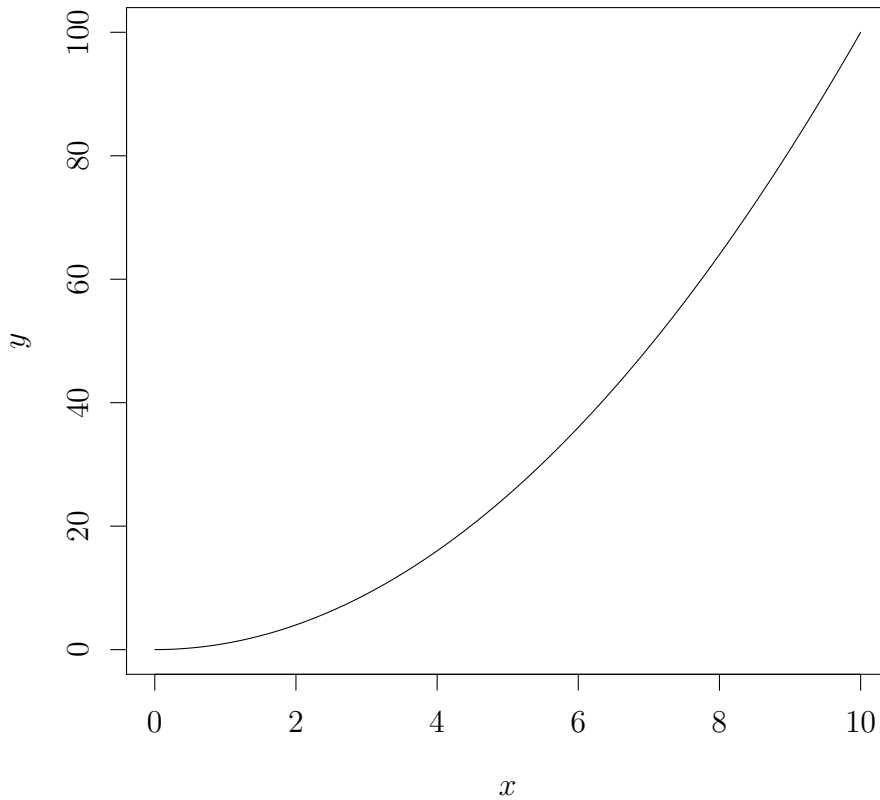
```

1 \section{Python programming language}
2 \ix{Python programming language}
3
4 \lightgreen{Python can be set up to use \LaTeX\ fonts.}
5
6 \includegraphics{gr-python2.pdf}
7
8 This is the |misc/gr-python2.py| input file:
9 \MyI{misc/gr-python2.py}
10
11 I typed, on Linux,
12 \Shell{./gr-python2.py}
13 in the |misc| subdirectory
14 to make the\
15 |graphics/gr-python2.pdf| output file.

```

## L.4 R programming language

R can be set up to use  $\text{\LaTeX}$  fonts.



This is the misc/gr-r.R input file:

```

1 # gr-r.R    2021-11-24    Mark Senn    https://bit.ly/markseenn
2
3 # See
4 #   https://texample.net/tikz/examples/tikzdevice-demo/
5 # for information on tikzDevice.
6
7 # Load the tikzDevice package.
8 # If you don't have it, install with
9 #   install.packages("tikzDevice", repos="http://R-Forge.R-project.org")
10 require(tikzDevice)
11
12 tikz(file = '../gr-r.tex', height=5, width=5)
13
14 curve(x^2, from=0, to=10, xlab="$x$", xlim=c(0,10), ylab="$y$", ylim=c(0,100))
15
16 dev.off()

```

I typed, on Linux, **R CMD BATCH gr-r** in the misc subdirectory to make the `gr-r.tex` outfile file.

```

1
2 \section{R programming language}
3 \ix{R programming language}
4
5 \lightgreen{R can be set up to use \LaTeX\ fonts.}

```

```

6
7 \input{gr-r.tex}
8
9 This is the |misc/gr-r.R| input file:
10 \MyI{misc/gr-r.R}
11
12 I typed, on Linux,
13 \Shell{R CMD BATCH gr-r}
14 in the |misc| subdirectory to make the |gr-r.tex| outfile file.

```

## L.5 TikZ L<sup>A</sup>T<sub>E</sub>X package

TikZ uses L<sup>A</sup>T<sub>E</sub>X fonts.

```

1
2 \section{\TikZLogo\ \LaTeX\ package}
3 \index{\TikZ@\TikZLogo\ \LaTeX\ package}
4 \todoindex{\TikZLogo\ \LaTeX\ package}
5
6 \lightgreen{\TikZLogo\ uses \LaTeX\ fonts.}

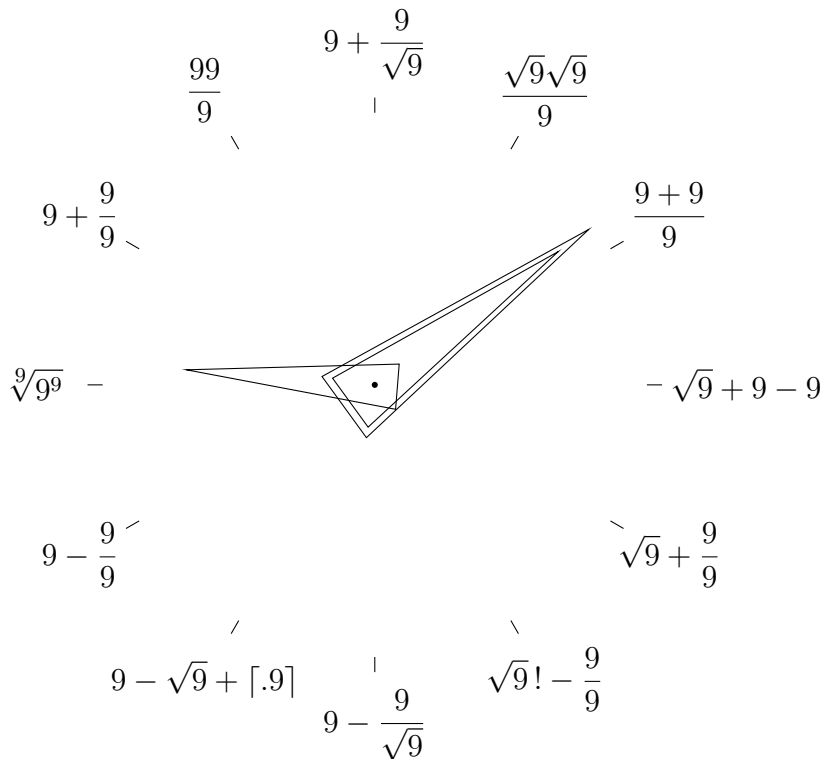
```

### L.5.1 Clock example

```

1
2 \subsection{Clock example}
3 \index{clock \TikZLogo\ example}
4 \todoindex{clock \TikZLogo\ example}

```



```

1
2 \index{\TikZ@\TikZLogo}

```

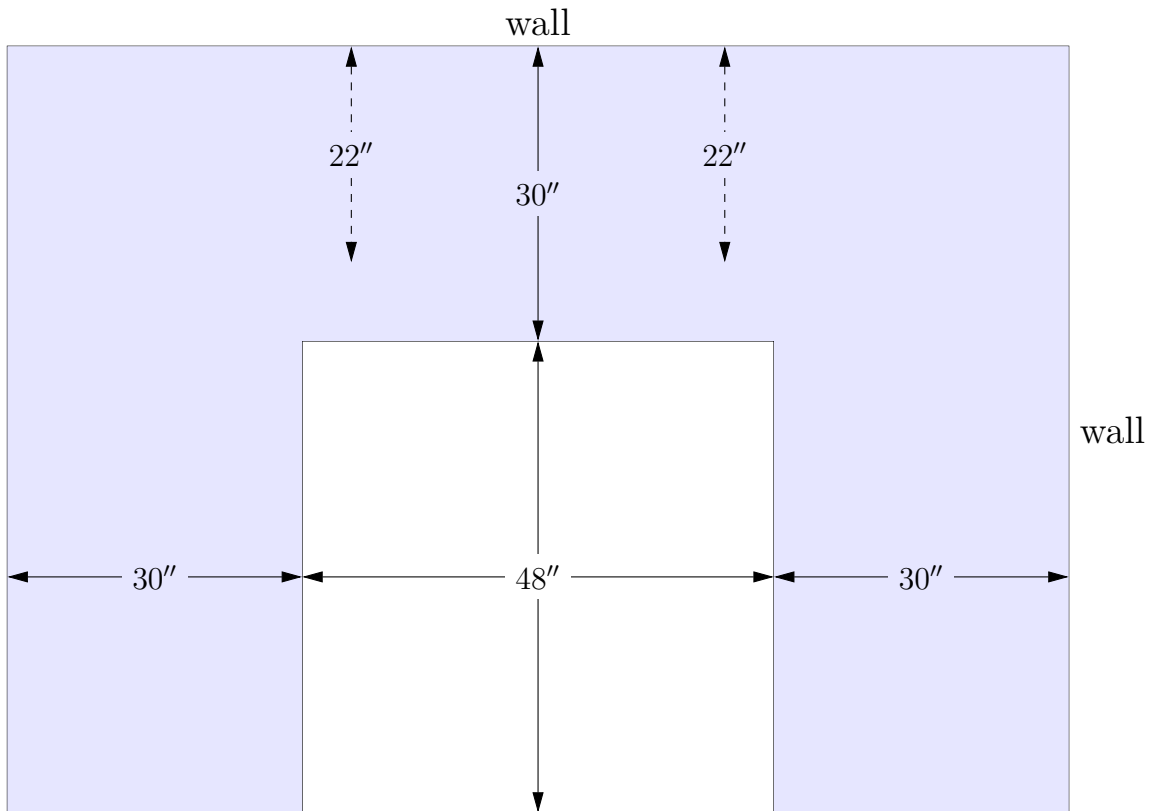
```

3
4 \hbox to\textwidth{%
5   \hfil
6   % The idea for this clock was originally from a Google+ posting by Afamefuna ‘‘Ferdy’’ Ibeabuchia.
7   \begin{tikzpicture}
8     \def\CenterRadius{0.04cm}
9     \def\InnerTickRadius{3.6cm}
10    \def\OuterTickRadius{3.8cm}
11    % Make \LR be an abbreviation for \LabelRadius so the
12    % lines below will fit within the width of the page.
13    \def\LabelRadius{4.5cm}    \let\LR=\LabelRadius
14    \def\HourHandRadius{2.5cm} \def\HourHandBase{0.3cm}
15    \def\MinuteHandRadius{3cm} \def\MinuteHandBase{0.4cm}
16    \def\SecondHandRadius{3.5cm} \def\SecondHandBase{0.5cm}
17    \def\DS{\displaystyle}
18    \fill (0,0) circle (\CenterRadius);
19    \foreach \i in {0,30,...,330}
20    \draw (\i:\InnerTickRadius)--(\i:\OuterTickRadius);
21    \node at ( 0:\LR) {$\DS \quad \sqrt{9 + 9 - 9}$};           % 3
22    \node at ( 30:\LR) {$\DS \frac{9+9}{9}$};                 % 2
23    \node at ( 60:\LR) {$\DS \frac{\sqrt{9}\sqrt{9}}{9}$};   % 1
24    \node at ( 90:\LR) {$\DS 9 + \frac{9}{\sqrt{9}}$};       % 12
25    \node at (120:\LR) {$\DS \frac{99}{9}$};                 % 11
26    \node at (150:\LR) {$\DS 9 + \frac{99}{9}$};            % 10
27    \node at (180:\LR) {$\DS \sqrt[\scriptstyle 9]{9^9}$};   % 9
28    \node at (210:\LR) {$\DS 9 - \frac{99}{9}$};            % 8
29    \node at (240:\LR) {$\DS 9 - \sqrt{9 + \lceil.9\rceil}$}; % 7
30    \node at (270:\LR) {$\DS 9 - \frac{9}{\sqrt{9}}$};       % 6
31    \node at (300:\LR) {$\DS \sqrt{9},! - \frac{99}{9}$};   % 5
32    \node at (330:\LR) {$\DS \sqrt{9 + \frac{99}{9}}$};      % 4
33    % In the following
34    % ABBREVIATION    DESCRIPTION
35    % deg             degrees
36    % min             minutes
37    % sec             seconds
38    % for second hand:
39    % (9 sec/60 sec) * 360 deg = 54 deg;
40    % 90 deg - 54 deg = 36 deg
41    \draw[rotate around={36:(0,0)}]
42    (-\SecondHandBase,\SecondHandBase) -- (\SecondHandRadius,0)
43    -- (-\SecondHandBase,-\SecondHandBase) -- cycle;
44    % for minute hand:
45    % (9 min/60 min) * 360 deg = 54 deg;
46    % 90 deg - 54 deg = 36 deg
47    \draw[rotate around={36:(0,0)}]
48    (-\MinuteHandBase,\MinuteHandBase) -- (\MinuteHandRadius,0)
49    -- (-\MinuteHandBase,-\MinuteHandBase) -- cycle;
50    % for hour hand:
51    % (9 min * (60 sec/1 min)) + 9 sec) / 3600 sec
52    % = 549 sec / 3600 sec = 0.1525
53    % The hour hand is 0.1525 of the way from 9:00 to 10:00.
54    % Each hour is 30 degrees on the clock, so the hour hand
55    % position is
56    % 30 deg * 0.1525 = 4.575 deg past 9:00
57    % 180 deg - 4.575 deg = 175.425 deg
58    \draw[rotate around={175.425:(0,0)}]
59    (-\HourHandBase,\HourHandBase) -- (\HourHandRadius,0)
60    -- (-\HourHandBase,-\HourHandBase) -- cycle;
61  \end{tikzpicture}
62  \hfil
63 }

```



## L.5.2 counter example



```

1
2 \newpage
3
4 \subsection{counter example}
5 \label{ss:counter-example}
6 \index{counter \TikZLogo\ example}
7 \todoindex{counter \TikZLogo\ example}
8
9 \begin{tikzpicture}[scale=0.13]
10 % Define points.
11 \coordinate (p11) at ( 0, 78);
12 \coordinate (p14) at ( 35, 78);
13 \coordinate (p15) at ( 54, 78);
14 \coordinate (p16) at ( 73, 78);
15 \coordinate (p19) at (108, 78);
16 \coordinate (p24) at ( 35, 67);
17 \coordinate (p26) at ( 73, 67);
18 \coordinate (p35) at ( 54, 63);
19 \coordinate (p44) at ( 35, 56);
20 \coordinate (p46) at ( 73, 56);
21 \coordinate (p53) at ( 30, 48);
22 \coordinate (p55) at ( 54, 48);
23 \coordinate (p57) at ( 78, 48);
24 \coordinate (p69) at (108, 39);
25 \coordinate (p71) at ( 0, 24);
26 \coordinate (p72) at ( 15, 24);
27 \coordinate (p73) at ( 30, 24);
28 \coordinate (p75) at ( 54, 24);
29 \coordinate (p77) at ( 78, 24);
30 \coordinate (p78) at ( 93, 24);

```

```

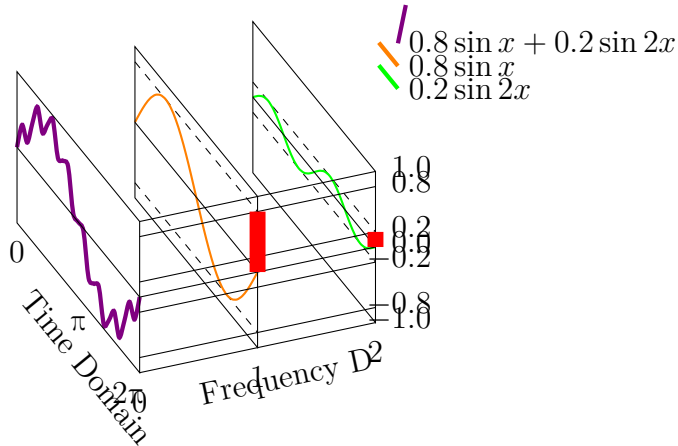
31     \coordinate (p79) at (108, 24);
32 \coordinate (p81) at ( 0, 0);
33     \coordinate (p83) at ( 30, 0);
34     \coordinate (p85) at ( 54, 0);
35     \coordinate (p87) at ( 78, 0);
36     \coordinate (p89) at (108, 0);
37 % Put "wall" above drawing.
38 \draw (p15) node[above] {\large wall};
39 % Plot outer edge.
40 \draw (p81) -- (p11) -- (p19) -- (p89);
41 % Plot inner edge.
42 \draw (p83) -- (p53) -- (p57) -- (p87);
43 % Color the counter.
44 \fill[blue!10] (p81) -- (p11) -- (p19) -- (p89) -- (p87) -- (p57) -- (p53) -- (p83) -- cycle;
45 % Vertical measurement lines.
46 \draw[dashed, arrows = {Stealth[inset=0pt, angle=30:8pt]-Stealth[inset=0pt, angle=30:8pt]]
47     (p14) -- (p44);
48 \draw (p24) node[fill=blue!10] {$22'$};
49 \draw[arrows = {Stealth[inset=0pt, angle=30:8pt]-Stealth[inset=0pt, angle=30:8pt]] (p15) -- (p55);
50 \draw (p35) node[fill=blue!10] {$30'$};
51 \draw[dashed, arrows = {Stealth[inset=0pt, angle=30:8pt]-Stealth[inset=0pt, angle=30:8pt]]
52     (p16) -- (p46);
53 \draw (p26) node[fill=blue!10] {$22'$};
54 \draw[arrows = {Stealth[inset=0pt, angle=30:8pt]-Stealth[inset=0pt, angle=30:8pt]] (p55) -- (p85);
55 % Horizontal measurement lines.
56 \draw[arrows = {Stealth[inset=0pt, angle=30:8pt]-Stealth[inset=0pt, angle=30:8pt]] (p71) -- (p73);
57 \draw (p72) node[fill=blue!10] {$30'$};
58 \draw[arrows = {Stealth[inset=0pt, angle=30:8pt]-Stealth[inset=0pt, angle=30:8pt]] (p73) -- (p77);
59 \draw (p75) node[fill=white] {$48'$};
60 \draw[arrows = {Stealth[inset=0pt, angle=30:8pt]-Stealth[inset=0pt, angle=30:8pt]] (p77) -- (p79);
61 \draw (p78) node[fill=blue!10] {$30'$};
62 % Put "wall" to the right of drawing.
63 \draw (p69) node[right] {\large wall};
64 \end{tikzpicture}

```

### L.5.3 Fourier transform example

The Fourier transform decomposes a function into the frequencies that make it up. The inverse Fourier transformation combines the contributions of all the different frequencies to recover the original function.

(Mark Senn <mark@purdue.edu> wrote sales@aavos.be on 2021-09-03 to ask permission to use [Fourier transform](#) as the starting point for an example *TikZ* figure. Dominique Demurie <sales@aavos.be> replied on 2021-09-06 with “I think it is not an original drawing from us either. We had it for years on our website, but I cannot remember where we got it from. We don’t mind you using it for a thesis.”)



```

1
2 \subsection{Fourier transform example}
3 \label{ss:fourier-transform-example}
4 \index{Fourier transform \TikZLogo\ example}
5 \todoindex{Fourier transform \TikZLogo\ example}
6
7 The Fourier transform decomposes a function
8 into the frequencies that make it up.
9 The inverse Fourier transformation combines the contributions
10 of all the different frequencies to recover the original function.
11
12 (Mark Senn {\tt\char'074}mark@purdue.edu{\tt\char'076} wrote sales@aavos.be on 2021-09-03
13 to ask permission
14 to use
15 \href{https://aavos.eu/glossary/fourier-transform/}{Fourier transform}
16 as the starting point
17 for an example \TikZLogo\ figure.
18 Dominique Demurie {\tt\char'074}sales@aavos.be{\tt\char'076} replied
19 on 2021-09-06 with
20 ‘‘I think it is not an original drawing from us either.
21 We had it for years on our website,
22 but I cannot remember where we got it from.
23 We don’t mind you using it for a thesis.’’)
24
25 % Run this with
26 %   pdflatex --shell-escape t
27 % That makes the t.table.* files.
28 %
29 % See
30 %   https://ctan.math.washington.edu/tex-archive/graphics/pgf/base/doc/pgfmanual.pdf
31 %   PAGE   TOPIC
32 %   655    decorations.text library to draw text
33 %   1221   animations
34 %
35 % for text decorations, which includes text along a path information.
36 % Also see
37 %   https://tex.stackexchange.com/questions/427454/tikz-3dplot-and-rotation-of-coordinates
38 %   https://tex.stackexchange.com/questions/67573/tikz-shift-and-rotate-in-3d
39 %   http://tug.ctan.org/graphics/pgf/contrib/tikz-3dplot/tikz-3dplot_documentation.pdf
40 %   https://tex.stackexchange.com/questions/45848/rotate-node-text-and-use-relative-positioning-in-tikz
41
42 % was scale = 2
43 \begin{tikzpicture}[domain=0:6.283185, rotate around y=-55, scale=1]
44
45 % total plot
46 \begin{scope}[canvas is xy plane at z=0]

```

```

47     \node[below=3pt] at (0,          -1) {0};
48     \node[below=3pt] at (3.141593, -1) {\pi$};
49     \node[below=5pt] at (5.683185, -1) {2\pi$};
50     \draw[ultra thick,color=violet] plot[id=total,smooth] function{0.8*sin(x)+0.2*sin(8*x)};
51     \draw[thin,color=black] (0,-1) -- (0,1) -- (6.283185,1) -- (6.283185,-1) -- cycle;
52     \draw[thin,color=black] (0,0) -- (6.283185,0);
53     \path[decorate,decoration={text along path,
54 % |\LARGE|
55     text={Time Domain}}] (0.1,-2) -- (6.283185,-2);
56     % $s(t)$
57     \end{scope}
58
59 % tall plot
60 \begin{scope}[canvas is xy plane at z=-1.5]
61     \draw[dashed] (0,0.8) -- (6.283185,0.8);
62     \draw[dashed] (0,-0.8) -- (6.283185,-0.8);
63     \draw[thick,color=orange] plot[id=tall,smooth] function{0.8*sin(x)};
64     \draw[thin,color=black] (0,-1) -- (0,1) -- (6.283185,1) -- (6.283185,-1) -- cycle;
65     \draw[thin,color=black] (0,0) -- (6.283185,0);
66 \end{scope}
67
68 % short plot
69 \begin{scope}[canvas is xy plane at z=-3.0]
70     \draw[dashed] (0, 0.2) -- (6.283185, 0.2);
71     \draw[dashed] (0,-0.2) -- (6.283185, -0.2);
72     \draw[thick,color=green] plot[id=short,smooth] function{0.2*sin(2*x)};
73     \draw[thin,color=black] (0,-1) -- (0,1) -- (6.283185,1) -- (6.283185,-1) -- cycle;
74     \draw[thin,color=black] (0,0) -- (6.283185,0);
75 \end{scope}
76
77 % frequency plot
78 \begin{scope}[canvas is zy plane at x=6.283185]
79     \node[below=3pt] at ( 0.0,-1) {0};
80     \node[below=3pt] at (-1.5,-1) {1};
81     \node[below=3pt] at (-3.0,-1) {2};
82     \draw[thin,color=black] (0,-1.0) -- (-3.0,-1.0); \node[above=-9pt] at (-3.3,-1.0) {\$-1.0$};
83     \draw[thin,color=black] (0,-0.8) -- (-3.0,-0.8); \node[above=-9pt] at (-3.3,-0.8) {\$-0.8$};
84     \draw[thin,color=black] (0,-0.2) -- (-3.0,-0.2); \node[above=-9pt] at (-3.3,-0.2) {\$-0.2$};
85     \draw[thin,color=black] (0, 0.0) -- (-3.0, 0.0); \node[above=-9pt] at (-3.3, 0.0) {\$\phantom-0.0$};
86     \draw[thin,color=black] (0, 0.2) -- (-3.0, 0.2); \node[above=-9pt] at (-3.3, 0.2) {\$\phantom-0.2$};
87     \draw[thin,color=black] (0, 0.8) -- (-3.0, 0.8); \node[above=-9pt] at (-3.3, 0.8) {\$\phantom-0.8$};
88     \draw[thin,color=black] (0, 1.0) -- (-3.0, 1.0); \node[above=-9pt] at (-3.3, 1.0) {\$\phantom-1.0$};
89     \draw[line width=6pt,color=red] (-1.5,0) -- (-1.5,0.8);
90     \draw[line width=6pt,color=red] (-3.0,0) -- (-3.0,0.2);
91     \path[decorate,decoration={text along path,
92 % |\LARGE|
93     text={Frequency Domain}}] (-0.8,-1.6) -- (-3.0,-1.6);
94     % $\omega$
95     \end{scope}
96
97 %% legend
98 %% Wolfram Language code:
99 %%     In[1]:= ry[theta_] :=
100 %%     {
101 %%         {Cos[theta Degree], 0, Sin[theta Degree]},
102 %%         {0, 1, 0},
103 %%         {-Sin[theta Degree], 0, Cos[theta Degree]}
104 %%     }
105 %%
106 %%     ry[55] . {Pi, 0.7, -3.5}
107 %%     # Out[] = {-1.06509, 0.7, -4.58096}
108 %%     ry[55] . {(3/4)Pi, 0.7, -3.5}
109 %%     # Out[] = {-1.51557, 0.7, -3.9376}
110

```

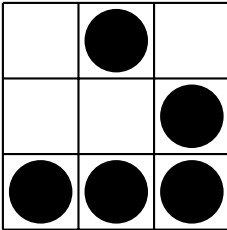
```

111 \draw[ultra thick,color=violet] (2.45782, 1.7, -4.33538) -- (1.06509, 0.7, -4.58096);
112 \node[right] at (1.06509, 0.7, -4.58096)
113 \draw[ultra thick,color=orange] (0.08509, 0.4, -4.58096) -- (1.06509, 0.4, -4.58096);
114 \node[right] at (1.06509, 0.4, -4.58096) {$0.8\sin x$};
115 \draw[ultra thick,color=green] (0.08509, 0.1, -4.58096) -- (1.06509, 0.1, -4.58096);
116 \node[right] at (1.06509, 0.1, -4.58096) {$0.2\sin 2x$};
117 \end{tikzpicture}
118

```

## L.5.4 Glider example

The glider is a pattern from the Game of Life, and it's used as an emblem representing the hacker community.



```

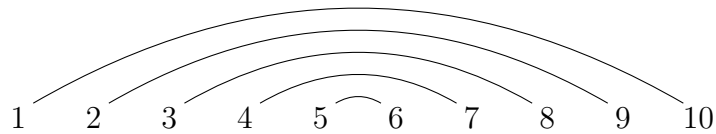
1
2 \subsection{Glider example}
3 \ix{Hirzel, Alex}
4 \index{glider \TikZLogo\ example}
5 \todoindex{glider \TikZLogo\ example}
6
7 The glider
8 is a pattern from the Game of Life,
9 and it's used as an emblem representing the hacker community.
10
11 \begin{tikzpicture}[thick]
12 \draw (0,0) grid (3,3);
13 \foreach \c in {(0,0), (1,0), (2,0), (2,1), (1,2)}
14 \fill \c + (0.5,0.5) circle (0.42);
15 \end{tikzpicture}

```

## L.5.5 Sum of 1 to $n$ example

What is the sum of 1 to  $n$ ?

Pair the numbers 1 and 10, 2 and 9, ... :



So

$$\begin{aligned}
 \sum_1^n &= \text{how many pairs of numbers} \times \text{the sum of each pair} \\
 &= \binom{n}{2} (n + 1) \\
 &= \frac{n(n + 1)}{2}
 \end{aligned}
 \tag{L.1}$$

This also works if  $n$  is an odd number. (The famous mathematician Gauss reportedly added the numbers 1–100 quickly in 1784 but the best reference I could find [66, page 3–4] did not state which method he used.)

```

1
2 % If you use the silence package change
3 \subsection{Sum of 1 to \(\n\) example}
4 % to
5 % \subsection{Sum of 1 to $n$ example}
6 % to avoid having the silence package apparently go into an infinite
7 % loop.
8 % \ix{sum of 1 to \(\n\)}}
9
10 What is the sum of \(\text{1 to } n\)?
11
12 Pair the numbers 1 and 10, 2 and 9, \ldots\,:
13
14 \hbox to\textwidth{%
15   \hss % horizontal stretch or shrink as needed
16   \vspace*{0.25in}
17   % Curves leave a node at a 30 degree angle
18   % and enter a node at a 150 degree angle.
19   \begin{tikzpicture}[out=30,in=150]
20     \node at (1,0) {1};
21     \node at (2,0) {2};
22     \node at (3,0) {3};
23     \node at (4,0) {4};
24     \node at (5,0) {5};
25     \node at (6,0) {6};
26     \node at (7,0) {7};
27     \node at (8,0) {8};
28     \node at (9,0) {9};
29     \node at (10,0) {10};
30     \draw (1.2, 0.2) to (9.8, 0.2)
31           (2.2, 0.2) to (8.8, 0.2)
32           (3.2, 0.2) to (7.8, 0.2)
33           (4.2, 0.2) to (6.8, 0.2)
34           (5.2, 0.2) to (5.8, 0.2);
35   \end{tikzpicture}%
36   \hss
37 }
38

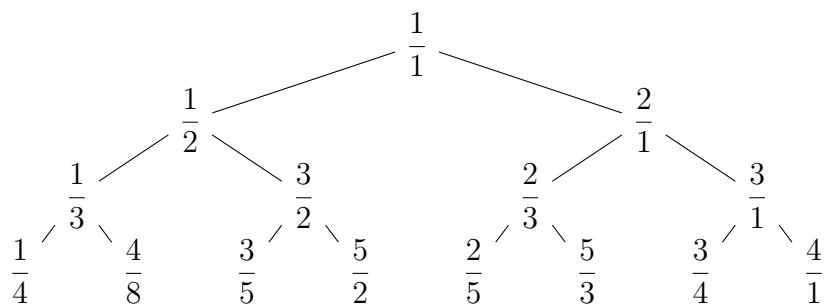
```

```

39 So
40 \begin{align}
41 % Since i is interpreted as a constant and is an upright font by default
42 % I'm using {\mit i} so it is in a math italic font.
43 \sum_{i=1}^n \text{\textit{i}} = \text{how many pairs of numbers}
44 \times \text{the sum of each pair}
45 = \left(\frac{n+1}{2}\right) (n+1)
46 = \frac{n(n+1)}{2}
47 \end{align}
48 This also works if  $n$  is an odd number.
49 (The famous mathematician Gauss reportedly added
50 the numbers 1--100 quickly in 1784
51 but the best reference I could find
52 \cite[page 3--4]{waltershausen1856}
53 did not state which method he used.)

```

## L.5.6 Tree example



The node with value  $\frac{n}{d}$

with additional conditions	has	with value
(none)	left child	$\frac{n}{n+d}$
(none)	right child	$\frac{n+d}{d}$
$n < d$	parent	$\frac{n}{d-n}$
$n = d$	no parent	(not applicable)
$n > d$	parent	$\frac{n-d}{d}$

```

1
2 \newpage
3
4 \subsection{Tree example}
5 \ix{???, ???}
6 \index{tree \TikZLogo\ example}
7 \todoindex{tree \TikZLogo\ example}
8
9 {
10 \def\f#1#2{\displaystyle\frac #1#2$}
11 \begin{tikzpicture}%
12 [%
13 level 1/.style={sibling distance=60mm},
14 level 2/.style={sibling distance=30mm},
15 level 3/.style={sibling distance=15mm}
16 ]
17 \node {\f 11}
18   child {node {\f 12$}
19     child {\f 13}
20     child {node {\f 14}}
21     child {node {\f 48}}
22   }
23   child {node {\f 32}
24     child {node {\f 35}}
25     child {node {\f 52}}
26   }
27 }
28 child {node {\f 21}
29   child {node {\f 23}

```



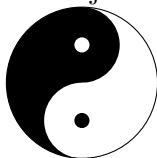
```

30         child {node {\f 25}}
31         child {node {\f 53}}
32     }
33     child {node {\f 31}}
34         child {node {\f 34}}
35         child {node {\f 41}}
36     }
37 };
38 \end{tikzpicture}
39
40 \vspace*{4pt}
41 The node with value \f nd\[2pt]
42 \indent\hspace*{4\parindent}
43 \begin{tabular}{@{}l|l|l@{}}
44     \bfseries with additional conditions& \bfseries has& \bfseries with value\\
45     \noalign{\vspace{2pt}}
46     (none)& left child& \f n{{n+d}}\\
47     \noalign{\vspace{12pt}}
48     (none)& right child& \f {{n+d}}d\\
49     \noalign{\vspace{12pt}}
50     $n<d$& parent& \f n{{d-n}}\\
51     \noalign{\vspace{12pt}}
52     $n=d$& no parent& (not applicable)\\
53     \noalign{\vspace{12pt}}
54     $n>d$& parent& \f {{n-d}}d\\
55 \end{tabular}
56 }

```

### L.5.7 Yin and yang example

This Yin and yang example was done by Thomas G. Kristensen [67]. This is the “traditional Taijitu symbol from Chinese philosophy”.



```

1
2
3 \subsection{Yin and yang example}
4
5 This Yin and yang example was done by Thomas G. Kristensen \cite{kristensen}.
6 This is the “traditional Taijitu symbol from Chinese philosophy”.
7 \ix{Kristensen, Thomas G.//Taijitu symbol//Yin and yang symbol}
8
9 \index{TikZ@TikZLogo}
10 \begin{tikzpicture}
11     % Yin and yang
12     % Author: Thomas G. Kristensen
13
14     % color one half of a unit circle
15     \begin{scope}
16         \clip (0,0) circle (1cm);
17         \fill[black] (0cm,1cm) rectangle (-1cm, -1cm);
18     \end{scope}
19
20     % fill heads
21     \fill[black] (0,0.5) circle (0.5cm);
22     \fill[white] (0,-0.5) circle (0.5cm);

```

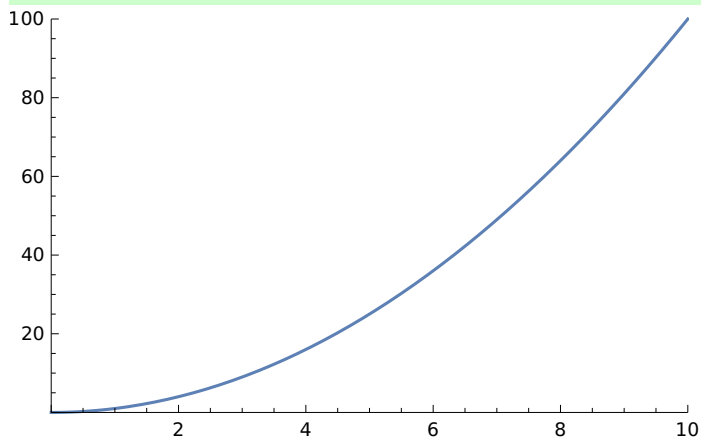
```

23
24 % fill eyes
25 \fill[white] (0,0.5) circle (0.1cm);
26 \fill[black] (0,-0.5) circle (0.1cm);
27
28 % outer line
29 \draw (0,0) circle (1cm);
30
31 \end{tikzpicture}

```

## L.6 Wolfram Language (Mathematica uses this)

Wolfram Language can be set up to use L<sup>A</sup>T<sub>E</sub>X fonts.



This is the misc/gr-mathematica.ma input file

```

1  (*
2     MaTeX is a Wolfram Language package to use LaTeX fonts in
3     Wolfram Language graphics. See
4         http://szhorvat.net/pelican/latex-typesetting-in-mathematica.html
5     for instructions on how to use MaTeX.
6  *)
7
8  (* Install MaTeX. *)
9  ResourceFunction["MaTeXInstall"] [];
10
11 (* Load MaTeX. *)
12 <<MaTeX';
13
14 latexStyle = {FontFamily->"Latin Modern Roman", FontSize->10};
15
16 g = Graphics[
17   Plot[x^2,
18     {x,0,10},
19     BaseStyle->latexStyle,
20     PlotRange->{{0,10},{0,100}}
21   ]
22 ];
23 I
24 Export["../graphics/gr-mathematica.pdf", g];

```

I typed, on Linux, `math < gr-mathematica.ma` in the misc subdirectory to make the `graphics/gr-mathematica.pdf` output file.

```

1
2 \section{Wolfram Language (Mathematica uses this)}

```

```
3 \ix{Mathematica}
4 \ix{Wolfram Language}
5
6 \lightgreen{Wolfram Language can be set up to use \LaTeX\ fonts.}
7
8 \includegraphics{gr-mathematica.pdf}
9
10 This is the |misc/gr-mathematica.ma| input file
11 \MyI{misc/gr-mathematica.ma}
12
13 I typed, on Linux,
14 \Shell{math < gr-mathematica.ma}
15 in the |misc| subdirectory
16 to make the |graphics/gr-mathematica.pdf| output file.
```

## M. HOW TO DEBUG L<sup>A</sup>T<sub>E</sub>X PROBLEMS

```
1 \chapter
2 [HOW TO DEBUG LATEX PROBLEMS]%
3 {HOW TO DEBUG \LaTeX\ PROBLEMS}
4 \ix{debugging \LaTeX//How to Debug \LaTeXLogo\ Problems appendix}
```

Add more content here.

```
1
2 Add more content here.
3 \todoerror{add more content here}
```

In LuaL<sup>A</sup>T<sub>E</sub>X error messages, the 1 in, for example, 1.987 means line. 1.987 means line 987.

**! Undefined control sequence. 1.*line\_number* \command}**

The *command* on *line\_number* of the current file does not exist. It may be misspelled.

## N. IGNORE THESE REFERENCES—THEY ARE WRONG

```
1 \chapter{IGNORE THESE REFERENCES---THEY ARE WRONG}
```

You may have seen these references on the web. Ignore them—they're wrong.

```
1
2 You may have seen these references on the web.
3 Ignore them---they're wrong.
```

### A Manual for the Preparation of [Purdue] Graduate Theses [36]

Parts of this are out of date.

Thesis Help <thesishelp@purdue.edu> wrote on March 20, 2023:

Please look for current information on the *Templates* web page [68].

```
1
2 \noindent
3 \textbf{A Manual for the Preparation of [Purdue] Graduate Theses}
4 \cite{thesis2017}
5
6 \begin{quote}
7   Parts of this are out of date.
8
9   Thesis Help \(<\)thesishelp@purdue.edu\(>\) wrote on March 20, 2023:
10  \begin{quote}
11    Please look for current information on the
12    \citetitle{thesisanddissertationofficeb}
13    web page
14    \cite{thesisanddissertationofficeb}.
15  \end{quote}
16 \end{quote}
```

### Purdue Online Writing Lab, IEEE Reference List [69]

The IEEE (The world's largest technical professional organization for the advancement of technology) has changed their references format from, for example,

[1] W. K. Chen, *Linear Networks and Systems*. Belmont, CA: Wadsworth Press, 2003.

to

[1] W. K. Chen, *Linear Networks and Systems*. Belmont, CA: Wadsworth Press, 2003.

See [70, page 2].

```
1
2 \noindent
3 \textbf{Purdue Online Writing Lab, IEEE Reference List}
4 \cite{owl}
5
6 \begin{quote}
7   The IEEE
8   (The world's largest technical professional organization
9   for the advancement
```

```

10 of technology)
11 has changed their references format from,
12 for example,
13
14 \noindent
15 \begin{tabular}{@{}ll@{}}
16 \noalign{\vspace*{6pt}}
17 [1]& W. K. Chen, Linear Networks and Systems. Belmont, CA: Wadsworth Press,\
18 \multispan{2}{2003.\hfil}\
19 \noalign{\vspace*{6pt}}
20 \noalign{\noindent to}
21 \noalign{\vspace*{6pt}}
22 [1]& W. K. Chen, Linear Networks and Systems. Belmont, CA: Wadsworth Press,\
23 & 2003.\hfil\
24 \noalign{\vspace*{6pt}}
25 \end{tabular}
26 See
27 \cite[page-2]{ieeedataport}.
28 \end{quote}

```

## O. LOGOS

These logos are defined in `pa-logos.sty`:

Input	Output	Used In
<code>\AMSMathLogo</code>	AMSMath	
<code>\BibLaTeXLogo</code>	Bib $\LaTeX$	
<code>\BiberLogo</code>	Biber	
<code>\CalligraphicAMSLaTeXLogo</code>	$\mathcal{A}\mathcal{M}\mathcal{S}$ - $\LaTeX$	
<code>\CircuiTikZLogo</code>	CircuiTikZ	
<code>\CTANLogo</code>	CTAN	
<code>\LaTeXLogo</code>	$\LaTeX$	
<code>\LuaLaTeXLogo</code>	Lua $\LaTeX$	
<code>\METAFONTLogo</code>	METAFONT	
<code>\METAPOSTLogo</code>	METAPOST	[71]
<code>\MetaPostLogo</code>	MetaPost	[71] and everywhere else I checked
<code>\NonCalligraphicAMSLaTeXLogo</code>	AMS- $\LaTeX$	
<code>\PurdueThesisLogo</code>	PurdueThesis	
<code>\PuThLogo</code>	PuTh	
<code>\siunitxLogo</code>	siunitx	
<code>\TeXLogo</code>	$\TeX$	
<code>\TeXLiveLogo</code>	$\TeX$ Live	
<code>\TikZLogo</code>	TikZ	
<code>\TeXUsersGroupLogo</code>	$\TeX$ Users Group	
<code>\TUGboatLogo</code>	<i>TUGboat</i>	

```

1 \chapter{LOGOS}
2
3 These logos are defined in |pa-logos.sty|:
4
5 \begin{tabular}{@{}l|l|l@{}}
6 \toprule
7 \bfseries Input& \bfseries Output& \bfseries Used In\\
8 \midrule
9 % From thesis.tex
10 % \newcommand{\tabularspace}{\noalign{\vspace*{2pt}}}
11 % \tabularspace
12 |\AMSMathLogo|& \AMSMathLogo\\[2pt]
13 |\BibLaTeXLogo|& \BibLaTeXLogo\\[2pt]
14 |\BiberLogo|& \BiberLogo\\[2pt]
15 |\CalligraphicAMSLaTeXLogo|& \CalligraphicAMSLaTeXLogo\\[2pt]
16 |\CircuiTikZLogo|& \CircuiTikZLogo\\[2pt]
17 |\CTANLogo|& \CTANLogo\\[2pt]
18 |\LaTeXLogo|& \LaTeXLogo\\[2pt]
19 |\LuaLaTeXLogo|& \LuaLaTeXLogo\\[2pt]
20 |\METAFONTLogo|& \METAFONTLogo\\[2pt]
21 |\METAPOSTLogo|& \METAPOSTLogo& \cite{hobby2024}\\[2pt]
22 |\MetaPostLogo|& \MetaPostLogo& \cite{hobby2024} and everywhere else I checked\\[2pt]
23 |\NonCalligraphicAMSLaTeXLogo|& \NonCalligraphicAMSLaTeXLogo\\[2pt]

```

```
24 |\PurdueThesisLogo|& \PurdueThesisLogo\|[2pt]
25 |\PuThLogo|& \PuThLogo\|[2pt]
26 |\siunitxLogo|& \siunitxLogo\|[2pt]
27 |\TeXLogo|& \TeXLogo\|[2pt]
28 |\TeXLiveLogo|& \TeXLiveLogo\|[2pt]
29 |\TikZLogo|& \TikZLogo\|[2pt]
30 |\TeXUsersGroupLogo|& \TeXUsersGroupLogo\|[2pt]
31 |\TUGboatLogo|& \TUGboatLogo\|[2pt]
32 \bottomrule
33 \end{tabular}
```



## P. NUMBERS AND UNITS

```
1 \chapter{NUMBERS AND UNITS}
```

Note to self: scientific prefixes, scientific suffixes, tables.

The PurdueThesis documentclass uses the siunitx [72] package with some extra definitions in the puthesis.cls file to do numbers and units.

```
1
2 Note to self: scientific prefixes, scientific suffixes, tables.
3
4 The \PurdueThesisLogo\ documentclass
5 uses the siunitx \cite{wright2024} package
6 with some extra definitions in the puthesis.cls file
7 to do numbers and units.
```

### P.1 Number Examples

```
1
2 \section{Number Examples}
```

Input	Output	Comment
<code>\num{-0.12345}</code>	-0.123 45	note the small space after the “3”
<code>\num{-0.1234}</code>	-0.1234	note no space between the “3” and “4”
<code>\num{-.123}</code>	-0.123	the “0.” is inserted automatically
<code>\num{123}</code>	123	
<code>\num{1234}</code>	1234	
<code>\num{12345}</code>	12 345	note the small space after the “2”
<code>\num{2e4}</code>	$2 \times 10^4$	
<code>\num{e5}</code>	$10^5$	
<code>\num{2.34567e6}</code>	$2.34567 \times 10^6$	note the small space after the “5”

```
1 \noindent\begin{tabular}{@{}l1l@{}}
2 \bfseries Input& \bfseries Output& \bfseries Comment\\
3 \tabularspace
4 \verb+\num{-0.12345}+& \num{-0.12345}& note the small space after the ‘3’\\
5 \verb+\num{-0.1234}+&
6 \num{-0.1234}&
7 note no space between the ‘3’ and ‘4’\\
8 \verb+\num{-.123}+& \num{-.123}& the ‘0.’ is inserted automatically\\
9 \verb+\num{123}+& \num{123}\\
10 \verb+\num{1234}+& \num{1234}\\
11 \verb+\num{12345}+& \num{12345}& note the small space after the ‘2’\\
12 \verb+\num{2e4}+& \num{2e4}\\
13 \verb+\num{e5}+& \num{e5}\\
14 \verb+\num{2.34567e6}+&
15 \num{2.34567e6}&
16 note the small space after the ‘5’\\
17 \end{tabular}
```

### P.2 Unit Examples

```
1
2 \section{Unit Examples}
```

See page 126 for the complete list of units defined by PurdueThesis.

Input	Output	Comment
<code>\si{\kg}</code>	kg	kilogram
<code>\si{\m}</code>	m	meter
<code>\si{\kg\per\m\squared}</code>	$\text{kg m}^{-2}$	= kg/m <sup>2</sup>

```

1
2 See page-\pageref{se:Complete-List-of-Units}
3 for the complete list
4 of units defined by \PurdueThesisLogo.
5
6 \noindent\begin{tabular}{@{}l}
7 \bfseries Input& \bfseries Output& \bfseries Comment\\
8 \tabularspace
9 \verb+\si{\kg}+& \si{\kg}& kilogram\\
10 \verb+\si{\m}+& \si{\m}& meter\\
11 \verb+\si{\kg\per\m\squared}+&
12 \si{\kg\per\m\squared}&
13 \ (= \si{\kg}/\si{\m\squared})\\
14 \end{tabular}

```

### P.3 Combined Number and Unit Examples

```

1
2 \section{Combined Number and Unit Examples}

```

Input	Output	Comment
<code>\SI{12}{\kg}</code>	12 kg	12 kilograms
<code>\SI{34}{\m}</code>	34 m	34 meters
<code>\SI{4.5e3}{\kg\per\m\squared}</code>	$4.5 \times 10^3 \text{ kg m}^{-2}$	= $4.5 \times 10^3 \text{ kg/m}^2$

```

1 \begin{tabular}{@{}l}
2 \bfseries Input& \bfseries Output& \bfseries Comment\\
3 \tabularspace
4 \verb+\SI{12}{\kg}+& \SI{12}{\kg}& 12 kilograms\\
5 \verb+\SI{34}{\m}+& \SI{34}{\m}& 34 meters\\
6 % The next input line is too wide for the margins
7 % so I'm splitting it into pieces.
8 \verb+\SI{4.5e3}{\kg\per\m\squared}+&
9 \SI{4.5e3}{\kg\per\m\squared}&
10 \ (= \num{4.5e3}\, \si{\kg}/\si{\m\squared})\\
11 \end{tabular}

```

How many seconds are in a non-leap year that does not have any leap seconds?

$$\begin{aligned}
 \frac{365 \cancel{\text{d}}}{\text{y}} \times \frac{24 \cancel{\text{h}}}{\cancel{\text{d}}} \times \frac{60 \cancel{\text{min}}}{\cancel{\text{h}}} \times \frac{60 \text{ s}}{\cancel{\text{min}}} &= 31\,536\,000 \frac{\text{s}}{\text{y}} \\
 &= 31\,536\,000 \text{ s y}^{-1} \\
 &\approx 3 \times 10^7 \text{ s y}^{-1} \\
 &\approx 30 \text{ million s y}^{-1}
 \end{aligned}$$

```

1
2 How many seconds are in a non-leap year that does not have any leap seconds?
3 % I tried several things and could not get \cancel to work with \per.
4 % Mark Senn 2019-12-29
5 \begin{align*}
6 \quad \frac{\SI{365}{\cancel{d}}{\si{y}}
7 \quad \times \frac{\SI{24}{\cancel{h}}{\si{\cancel{d}}}}{\si{\cancel{h}}}
8 \quad \times \frac{\SI{60}{\cancel{min}}{\si{\cancel{h}}}}{\si{\cancel{min}}}
9 \quad \times \frac{\SI{60}{\s}}{\si{\cancel{min}}}
10 % From http://www.emerson.emory.edu/services/latex/latex_119.html
11 % Spacing in Math Mode
12 % In a math environment, LaTeX ignores the spaces you type
13 % and puts in the spacing that it thinks is best. LaTeX formats
14 % mathematics the way it's done in mathematics texts. If you
15 % want different spacing, LaTeX provides the following four
16 % commands for use in math mode:
17 % \; - a thick space
18 % \: - a medium space
19 % \, - a thin space
20 % \! - a negative thin space
21 & = \num{31536000}\; \frac{\si{\s}}{\si{y}} \\
22 & = \SI{31536000}{\s\per y} \\
23 & \approx \SI{3e7}{\s\per y} \\
24 & \approx \text{30 million}\, \si{\s\per y} \\
25 \end{align*}

```

## P.4 Binary Prefixes

```

1
2 \section{Binary Prefixes}

```

The `\kibi...` `\yobi` commands are defined immediately after the `\usepackage{siunitx}` command in the `PurdueThesis.cls` file.

```

1
2 The
3 |\kibi|\ldots|\yobi|
4 commands are defined immediately after the
5 |\usepackage{siunitx}|
6 command in the PurdueThesis.cls file.

```

Power	Prefix	Symbol	Command	Comment
10	kibi	Ki	<code>\si{\kibi}</code>	2 <sup>10</sup> bytes is a KB, 10 <sup>3</sup> bytes is a KiB
20	mebi	Mi	<code>\si{\mebi}</code>	2 <sup>20</sup> bytes is a MB, 10 <sup>6</sup> bytes is a MiB
30	gibi	Gi	<code>\si{\gibi}</code>	2 <sup>30</sup> bytes is a GB, 10 <sup>9</sup> bytes is a GiB
40	tebi	Ti	<code>\si{\tebi}</code>	2 <sup>40</sup> bytes is a TB, 10 <sup>12</sup> bytes is a TiB
50	pebi	Pi	<code>\si{\pebi}</code>	2 <sup>50</sup> bytes is a PB, 10 <sup>15</sup> bytes is a PiB
60	exbi	Ei	<code>\si{\exbi}</code>	2 <sup>60</sup> bytes is a EB, 10 <sup>18</sup> bytes is a EiB
70	zebi	Zi	<code>\si{\zebi}</code>	2 <sup>70</sup> bytes is a ZB, 10 <sup>21</sup> bytes is a ZiB
80	yobi	Yi	<code>\si{\yobi}</code>	2 <sup>80</sup> bytes is a YB, 10 <sup>24</sup> bytes is a YiB

```

1
2 \newcolumntype{m}{>{\$}r<{\$}} % math mode version of "r" column type
3 \renewcommand{\t}[4]{(2^{#1}\) bytes is a #2, (10^{#3}\) bytes is a #4}
4 \begin{tabular}{@{m}llll@{}}
5 \multicolumn{1}{l}{\bfseries Power}& & & &

```

```

6     \bfseries Prefix&
7     \bfseries Symbol&
8     \bfseries Command&
9     \bfseries Comment\\
10    \tabularspace
11    10& kibi& \unit{\kibi\nounit}& \verb+\si{\kibi}+& \t{10}{KB}{3}{KiB}\\
12    20& mebi& \unit{\mebi\nounit}& \verb+\si{\mebi}+& \t{20}{MB}{6}{MiB}\\
13    30& gibi& \unit{\gibi\nounit}& \verb+\si{\gibi}+& \t{30}{GB}{9}{GiB}\\
14    40& tebi& \unit{\tebi\nounit}& \verb+\si{\tebi}+& \t{40}{TB}{12}{TiB}\\
15    50& pebi& \unit{\pebi\nounit}& \verb+\si{\pebi}+& \t{50}{PB}{15}{PiB}\\
16    60& exbi& \unit{\exbi\nounit}& \verb+\si{\exbi}+& \t{60}{EB}{18}{EiB}\\
17    70& zebi& \unit{\zebi\nounit}& \verb+\si{\zebi}+& \t{70}{ZB}{21}{ZiB}\\
18    80& yobi& \unit{\yobi\nounit}& \verb+\si{\yobi}+& \t{80}{YB}{24}{YiB}\\
19    \end{tabular}

```

## P.5 Decimal Prefixes

```

1
2 \section{Decimal Prefixes}

```

Power	Prefix	Symbol	Command	Comment
-30	quecto	q	<code>\si{\quecto}</code>	
-27	ronto	r	<code>\si{\quecto}</code>	
-24	yocto	y	<code>\si{\yocto}</code>	
-21	zepto	z	<code>\si{\zepto}</code>	
-18	atto	a	<code>\si{\atto}</code>	
-15	femto	f	<code>\si{\femto}</code>	
-12	pico	p	<code>\si{\pico}</code>	
-9	nano	n	<code>\si{\nano}</code>	
-6	micro	μ	<code>\si{\micro}</code>	
-3	milli	m	<code>\si{\milla}</code>	
-2	centi	c	<code>\si{\centi}</code>	
-1	deci	d	<code>\si{\deci}</code>	
1	deca	da	<code>\si{\deca}</code>	
1	deka	da	<code>\si{\deka}</code>	same as <code>\si{\deca}</code>
2	hecto	h	<code>\si{\hecto}</code>	
3	kilo	k	<code>\si{\kilo}</code>	
6	mega	M	<code>\si{\mega}</code>	
9	giga	G	<code>\si{\giga}</code>	
12	tera	T	<code>\si{\tera}</code>	
15	peta	P	<code>\si{\peta}</code>	
18	exa	E	<code>\si{\exa}</code>	
21	zetta	Z	<code>\si{\zetta}</code>	
24	yotta	Y	<code>\si{\yotta}</code>	
27	ronna	R	<code>\si{\ronna}</code>	
30	quetta	Q	<code>\si{\quetta}</code>	

```

1
2 \newcolumntype{m}{>{\$}r<{\$}} % math mode version of "r" column type
3 \begin{tabular}{@{}mllll@{}}

```

```

4 \multicolumn{1}{1}{\bfseries Power}&
5 \bfseries Prefix&
6 \bfseries Symbol&
7 \bfseries Command&
8 \bfseries Comment\\
9 \tabularspace
10 -30& quecto& \unit{\quecto\nounit}& \verb+\si{\quecto}+\\
11 -27& ronto& \unit{\ronto\nounit}& \verb+\si{\quecto}+\\
12 -24& yocto& \unit{\yocto\nounit}& \verb+\si{\yocto}+\\
13 -21& zepto& \unit{\zepto\nounit}& \verb+\si{\zepto}+\\
14 -18& atto& \unit{\atto\nounit}& \verb+\si{\atto}+\\
15 -15& femto& \unit{\femto\nounit}& \verb+\si{\femto}+\\
16 -12& pico& \unit{\pico\nounit}& \verb+\si{\pico}+\\
17 -9& nano& \unit{\nano\nounit}& \verb+\si{\nano}+\\
18 -6& micro& \unit{\micro\nounit}& \verb+\si{\micro}+\\
19 -3& milli& \unit{\milli\nounit}& \verb+\si{\milla}+\\
20 -2& centi& \unit{\centi\nounit}& \verb+\si{\centi}+\\
21 -1& deci& \unit{\deci\nounit}& \verb+\si{\deci}+\\
22 1& deca& \unit{\deca\nounit}& \verb+\si{\deca}+\\
23 1& deka& \unit{\deka\nounit}& \verb+\si{\deka}+& same as \verb+\si{\deca}+\\
24 2& hecto& \unit{\hecto\nounit}& \verb+\si{\hecto}+\\
25 3& kilo& \unit{\kilo\nounit}& \verb+\si{\kilo}+\\
26 6& mega& \unit{\mega\nounit}& \verb+\si{\mega}+\\
27 9& giga& \unit{\giga\nounit}& \verb+\si{\giga}+\\
28 12& tera& \unit{\tera\nounit}& \verb+\si{\tera}+\\
29 15& peta& \unit{\peta\nounit}& \verb+\si{\peta}+\\
30 18& exa& \unit{\exa\nounit}& \verb+\si{\exa}+\\
31 21& zetta& \unit{\zetta\nounit}& \verb+\si{\zetta}+\\
32 24& yotta& \unit{\yotta\nounit}& \verb+\si{\yotta}+\\
33 27& ronna& \unit{\ronna\nounit}& \verb+\si{\ronna}+\\
34 30& quetta& \unit{\quetta\nounit}& \verb+\si{\quetta}+\\
35 \end{tabular}

```

## P.6 SI Units

```

1
2 \section{SI Units}

```

The International System of Units (SI) is the modern form of the metric system. There are seven SI base units:

Name	Unit Of	Symbol
ampere	electrical current	A
candela	luminous intensity	cd
kelvin	thermodynamic temperature	K
kg	mass	kg
meter	length	m
mole	amount of substance	mol
second	time	s

```

1
2 The International System of Units
3 (SI)
4 % !!! Doing
5 % !!! \include{tipa}
6 % !!! in thesis.tex so \textprimstress works
7 % !!! apparently causes problems with math commands.
8 % !!! Figure out why the following doesn't work later.

```

```

9 % (
10 % SI,
11 % abbreviated from the French Syst\`eme International
12 % (d\textprimstress unit\`es)%
13 % )
14 is the modern form of the metric system.
15 There are seven SI base units:
16
17 \hspace{40pt}
18 \begin{tabular}{@{}l|l|l@{}}
19 \tabularspace
20 \bfseries Name& \bfseries Unit Of& \bfseries Symbol\\
21 \tabularspace
22 ampere& electrical current& \si{\ampere}\\
23 candela& luminous intensity& \si{\candela}\\
24 kelvin& thermodynamic temperature& \si{\kelvin}\\
25 kg& mass& \si{\kilogram}\\
26 meter& length& \si{\meter}\\
27 mole& amount of substance& \si{\mole}\\
28 second& time& \si{\second}\\
29 \end{tabular}

```

## P.7 Complete List of Units

```

1
2 \section{Complete List of Units}
3 \label{se:Complete-List-of-Units}

```

Table P.1. Units and Corresponding Symbols

Name	Unit Of	Symbol	Command	Is equal to
ampere	electrical current	A	<code>\si{\A}</code>	(SI base unit)
picoampere	"	pA	<code>\si{\pA}</code>	$10^{-12}$ A
nanoampere	"	nA	<code>\si{\nA}</code>	$10^{-9}$ A
microampere	"	$\mu$ A	<code>\si{\uA}</code>	$10^{-6}$ A
milliampere	"	mA	<code>\si{\mA}</code>	$10^{-3}$ A
kiloampere	"	kA	<code>\si{\kA}</code>	$10^3$ A
arcminute	plane angle	'	<code>\si{\arcmin}</code>	$(1/60)^\circ$
arcsecond	plane angle	"	<code>\si{\arcsec}</code>	$(1/60)'$
astronomical unit	length	au	<code>\si{\au}</code>	mean earth to sun distance
bar	pressure	bar	<code>\si{\bar}</code>	$10^{-5}$ Pa

*continued on next page*

Table P.1. *continued*

Name	Unit Of	Symbol	Command	Is equal to
millibar	"	mbar	<code>\si{\mbar}</code>	$10^{-3}$ bar
barn	area	b	<code>\si{\b}</code>	$10^{-28}$ m <sup>2</sup>
becquerel	radioactivity	Bq	<code>\si{\Bq}</code>	one radioactive decay per second
bel	sound intensity	B	<code>\si{\B}</code>	10 decibels
decibel	"	dB	<code>\si{\dB}</code>	$10^{-1}$ B
bohr	length	$a_0$	<code>\si{\bohr}</code>	distance between nucleus and electron in hydrogen atom
bushel	quantity	bu	<code>\si{\bu}</code>	see [73]
candela	luminous intensity	cd	<code>\si{\cd}</code>	(SI base unit)
coulomb	electrical charge	C	<code>\si{\C}</code>	$A s^{-1}$
dalton	mass	Da	<code>\si{\Da}</code>	another name for atomic mass unit
day	time	d	<code>\si{\d}</code>	86 400 s
degree	plane angle	°	<code>\si{\degree}</code>	1/360 of a circle
degree Celsius	temperature	°C	<code>\si{\celsius}</code>	xxx
electron mass	mass	$m_e$	<code>\si{\em}</code>	$9.109\,383\,713\,9 \times 10^{-31}$ kg
electron volt	energy	eV	<code>\si{\eV}</code>	$1.602\,176\,634 \times 10^{-19}$ J
millielectronvolt	"	meV	<code>\si{\meV}</code>	$10^{-3}$ eV
kiloelectronvolt	"	keV	<code>\si{\keV}</code>	$10^3$ eV
megaelectronvolt	"	MeV	<code>\si{\MeV}</code>	$10^6$ eV
gigaelectronvolt	"	GeV	<code>\si{\GeV}</code>	$10^9$ eV
teraelectronvolt	"	TeV	<code>\si{\TeV}</code>	$10^{12}$ eV
elementary charge	electrical charge	e	<code>\si{\ec}</code>	$\approx 1.6 \times 10^{19}$ C
farad	electrical capacitance	F	<code>\si{\F}</code>	$s^4 A^2 m^{-2} kg^{-1}$
femtofarad	"	fF	<code>\si{\fF}</code>	$10^{-15}$ F

*continued on next page*

Table P.1. *continued*

Name	Unit Of	Symbol	Command	Is equal to
picofarad	"	pF	<code>\si{\pF}</code>	$10^{-12}$ F
foot	length	ft	<code>\si{\ft}</code>	0.3048 m
gray	absorbed dose of ionizing radiation	Gy	<code>\si{\Gy}</code>	$\text{J kg}^{-1}$
hartree	energy used in molecular orbital calculations	$E_h$	<code>\si{\hartree}</code>	$4.359\,744\,722\,21 \times 10^{-18}$ J
hectare	area	ha	<code>\si{\ha}</code>	$10^4$ m <sup>2</sup>
henry	electrical inductance	H	<code>\si{\H}</code>	$\text{kg m}^2 \text{s}^{-2} \text{A}^{-2}$
hertz	frequency	Hz	<code>\si{\Hz}</code>	$\text{s}^{-1}$
millihertz	"	mHz	<code>\si{\mHz}</code>	$10^{-3}$ Hz
kilohertz	"	kHz	<code>\si{\kHz}</code>	$10^3$ Hz
megahertz	"	MHz	<code>\si{\MHz}</code>	$10^6$ Hz
gigahertz	"	GHz	<code>\si{\GHz}</code>	$10^9$ Hz
terahertz	"	THz	<code>\si{\THz}</code>	$10^{12}$ Hz
horsepower	power	hp	<code>\si{\hp}</code>	$\approx 745.7$ W, see [74] for details
hour	time	h	<code>\si{\h}</code>	3600 s
inch	length	in	<code>\si{\in}</code>	25.4 mm
joule	work or energy	J	<code>\si{\J}</code>	$\text{kg m}^2 \text{s}^{-2}$
microjoule	"	$\mu\text{J}$	<code>\si{\uJ}</code>	$10^{-6}$ J
millijoule	"	mJ	<code>\si{\mJ}</code>	$10^{-3}$ J
kilojoule	"	kJ	<code>\si{\kJ}</code>	$10^3$ J
megajoule	"	MJ	<code>\si{\MJ}</code>	$10^6$ J
katal	catalytic activity	kat	<code>\si{\kat}</code>	$\text{mol s}^{-1}$
kelvin	thermody- namic temperature	K	<code>\si{\K}</code>	(SI base unit)
kilogram	mass	kg	<code>\si{\kg}</code>	(SI base unit)
femtogram	"	fg	<code>\si{\fg}</code>	$10^{-15}$ g

*continued on next page*



Table P.1. *continued*

Name	Unit Of	Symbol	Command	Is equal to
picogram	"	pg	<code>\si{\pg}</code>	$10^{-12}$ g
nanogram	"	ng	<code>\si{\ng}</code>	$10^{-9}$ g
microgram	"	μg	<code>\si{\ug}</code>	$10^{-6}$ g
milligram	"	mg	<code>\si{\mg}</code>	$10^{-3}$ g
gram	"	g	<code>\si{\g}</code>	$10^{-3}$ kg
kilowatt hour	electrical energy	kWh	<code>\si{\kWh}</code>	kW h
knot	speed	kn	<code>\si{\kn}</code>	$M h^{-1}$
liter	volume	L	<code>\si{\L}</code>	$10^{-3}$ m <sup>3</sup>
microliter	"	μL	<code>\si{\uL}</code>	$10^{-6}$ L
milliliter	"	mL	<code>\si{\mL}</code>	$10^{-3}$ L
hectoliter	"	hL	<code>\si{\hL}</code>	$10^2$ L
lumen	luminous flux	lm	<code>\si{\lm}</code>	cd sr
lux	illumination	lx	<code>\si{\lx}</code>	$lm m^{-2}$
meter	length	m	<code>\si{\m}</code>	(SI base unit)
picometer	"	pm	<code>\si{\pm}</code>	$10^{-12}$ m
nanometer	"	nm	<code>\si{\nm}</code>	$10^{-9}$ m
micrometer	"	μm	<code>\si{\um}</code>	$10^{-6}$ m
millimeter	"	mm	<code>\si{\mm}</code>	$10^{-3}$ m
centimeter	"	cm	<code>\si{\cm}</code>	$10^{-2}$ m
decimeter	"	dm	<code>\si{\dm}</code>	$10^{-1}$ m
kilometer	"	km	<code>\si{\km}</code>	$10^3$ m
millimeter of mercury	pressure	mmHg	<code>\si{\mmHg}</code>	$\approx 133$ Pa
minute	time	min	<code>\si{\min}</code>	60 s
mole	amount of substance	mol	<code>\si{\mol}</code>	(SI base unit)
femtomole	"	fmol	<code>\si{\fmol}</code>	$10^{-15}$ mol
picomole	"	pmol	<code>\si{\pmol}</code>	$10^{-12}$ mol
nanomole	"	nmol	<code>\si{\nmol}</code>	$10^{-9}$ mol
micromole	"	μmol	<code>\si{\umol}</code>	$10^{-6}$ mol
millimole	"	mmol	<code>\si{\mmol}</code>	$10^{-3}$ mol

*continued on next page*

Table P.1. *continued*

Name	Unit Of	Symbol	Command	Is equal to
kilomole	"	kmol	<code>\si{\kmol}</code>	$10^3$ mol
nautical mile	distance	M	<code>\si{\M}</code>	1852 m
neper	gain, loss, and relative values	Np	<code>\si{\Np}</code>	1
newton	force	N	<code>\si{\N}</code>	$\text{kg m s}^{-2}$
millinewton	"	mN	<code>\si{\mN}</code>	$10^{-3}$ N
kilonewton	"	kN	<code>\si{\kN}</code>	$10^3$ N
meganewton	"	MN	<code>\si{\MN}</code>	$10^6$ N
ohm	electrical resistance	$\Omega$	<code>\si{\ohm}</code>	$\text{kg m}^2 \text{s}^{-3} \text{A}^{-2}$
milliohm	"	$\text{m}\Omega$	<code>\si{\mohm}</code>	$10^{-3}$ ohm
kiloohm	"	$\text{k}\Omega$	<code>\si{\kohm}</code>	$10^3$ ohm
megaohm	"	$\text{M}\Omega$	<code>\si{\Mohm}</code>	$10^6$ ohm
pascal	pressure	Pa	<code>\si{\Pa}</code>	$\text{kg m}^{-1} \text{s}^{-2}$
kilopascal	"	kPa	<code>\si{\kPa}</code>	$10^3$ Pa
megapascal	"	MPa	<code>\si{\MPa}</code>	$10^6$ Pa
gigapascal	"	GPa	<code>\si{\GPa}</code>	$10^9$ Pa
percent	hundredths	%	<code>\si{\percent}</code>	$10^{-2}$
pound	weight	lb	<code>\si{\lb}</code>	0.453 592 37 kg
radian	plane angular measurement	rad	<code>\si{\rad}</code>	$180/\pi$ °
reduced Planck constant	angular momentum	$\hbar$	<code>\si{\planckbar}</code>	$\approx 1.05 \times 10^{-34}$ J s
second	time	s	<code>\si{\s}</code>	(SI base unit)
attosecond	"	as	<code>\si{\as}</code>	$10^{-18}$ s
femtosecond	"	fs	<code>\si{\fs}</code>	$10^{-15}$ s
picosecond	"	ps	<code>\si{\ps}</code>	$10^{-12}$ s
nanosecond	"	ns	<code>\si{\ns}</code>	$10^{-9}$ s
microsecond	"	$\mu\text{s}$	<code>\si{\us}</code>	$10^{-6}$ s

*continued on next page*

Table P.1. *continued*

Name	Unit Of	Symbol	Command	Is equal to
millisecond	"	ms	<code>\si{\ms}</code>	$10^{-3} \text{ s}$
siemens	conductance	S	<code>\si{\S}</code>	$\text{kg}^{-1} \text{ m}^{-2} \text{ s}^3 \text{ A}^2$
sievert	dosage of ionizing radiation	Sv	<code>\si{\Sv}</code>	$\text{m}^2 \text{ s}^{-2}$
speed of light	speed	$c_0$	<code>\si{\clight}</code>	$299\,792\,458 \text{ m s}^{-1}$
standard deviation	amount of variation	SD	<code>\si{\SD}</code>	$\sqrt{\frac{1}{N-1} \sum_{i=1}^N (x_i - \bar{x})^2}$
steradian	measure of solid angles	sr	<code>\si{\sr}</code>	$1 \text{ m}^2 \text{ m}^{-2}$
tesla	magnetic flux density	T	<code>\si{\T}</code>	$\text{kg s}^{-2} \text{ A}^{-1}$
metric ton	mass	t	<code>\si{\t}</code>	$10^3 \text{ kg}$
volt	electrical potential difference	V	<code>\si{\V}</code>	$\text{kg m}^2 \text{ s}^{-3} \text{ A}^{-1}$
picovolt	"	pV	<code>\si{\pV}</code>	$10^{-12} \text{ V}$
nanovolt	"	nV	<code>\si{\nV}</code>	$10^{-9} \text{ V}$
microvolt	"	$\mu\text{V}$	<code>\si{\uV}</code>	$10^{-6} \text{ V}$
millivolt	"	mV	<code>\si{\mV}</code>	$10^{-3} \text{ V}$
kilovolt	"	kV	<code>\si{\kV}</code>	$10^3 \text{ V}$
watt	power	W	<code>\si{\W}</code>	$\text{kg m}^2 \text{ s}^{-3}$
microwatt	"	$\mu\text{W}$	<code>\si{\uW}</code>	$10^{-6} \text{ W}$
milliwatt	"	mW	<code>\si{\mW}</code>	$10^{-3} \text{ W}$
kilowatt	"	kW	<code>\si{\kW}</code>	$10^3 \text{ W}$
megawatt	"	MW	<code>\si{\MW}</code>	$10^6 \text{ W}$
gigawatt	"	GW	<code>\si{\GW}</code>	$10^9 \text{ W}$
weber	magnetic flux	Wb	<code>\si{\Wb}</code>	$\text{kg m}^2 \text{ s}^{-2} \text{ A}^{-1}$
yard	length	yd	<code>\si{\yd}</code>	$0.9144 \text{ m}$
year	time	y	<code>\si{\y}</code>	$\approx 365.25 \text{ d}$

```

1
2 {%
3 \ZZbaselinestretch{1}
4 \newcommand\vsp{\noalign{\vspace*{6pt}}}
5 % From
6 % https://tex.stackexchange.com/questions/31508/flushleft-with-p-option-in-tabular
7 % It's necessary to use the \arraybackslash in the last column,

```

```

8 % otherwise \\ would not end the table row. You can use \newline
9 % to end lines in the last column cells (and the regular \\ in
10 % the other column cells).
11 % ...
12 % If you need it often, consider defining a new column type using
13 % array features, as I did here:
14 % \newcolumntype{P}[1]{>{\raggedright\arraybackslash}p{#1}}
15 \newcolumntype{P}[1]{>{\raggedright\arraybackslash}p{#1}}%
16 % \begin{longtable}{@{}P{1.4in}P{1in}lP{1.8in}@{}}
17 % \begin{longtable}{@{}P{1in}P{1in}lP{1.8in}@{}}
18 % \begin{longtable}{@{}P{1.2in}P{1in}lP{1.8in}@{}}
19 % \begin{longtable}{@{}P{90.72pt}P{1in}lP{1.8in}@{}} % 1.2in (86.72pt) + 4pt = 90.72pt
20 \begin{longtable}{@{}P{1.4in}P{1in}lP{1.8in}@{}}% 1.2in (86.72pt) + 4pt = 90.72pt
21 \caption{Units and Corresponding Symbols}\\
22 \bfseries Name&
23 \bfseries Unit Of&
24 \bfseries Symbol&
25 \bfseries Command&
26 \bfseries Is equal to\\
27 \vsp
28 \endfirsthead
29 \caption[{}]{~\emph{continued}}\\
30 \bfseries Name&
31 \bfseries Unit Of&
32 \bfseries Symbol&
33 \bfseries Command&
34 \bfseries Is equal to\\
35 \vsp
36 \endhead
37 \vsp
38 % I don't know why the \hspace*{-7.5mm} was
39 % needed to center this horizontally.
40 \multicolumn{5}{@{}c@{}}{\hspace*{-7.5mm}\emph{continued on next page}}%
41 \endfoot
42 \endlastfoot
43 ampere&
44 electrical current&
45 \si{A}&
46 \verb+\si{A}+&
47 (SI base unit)\\
48 \quad picoampere&
49 \ditto&
50 \si{pA}&
51 \verb+\si{pA}+&
52 \SI{e-12}{A}\\
53 \quad nanoampere&
54 \ditto&
55 \si{nA}&
56 \verb+\si{nA}+&
57 \SI{e-9}{A}\\
58 \quad microampere&
59 \ditto&
60 \si{uA}&
61 \verb+\si{uA}+&
62 \SI{e-6}{A}\\
63 \quad milliampere&
64 \ditto&
65 \si{mA}&
66 \verb+\si{mA}+&
67 \SI{e-3}{A}\\
68 \quad kiloampere&
69 \ditto&
70 \si{kA}&
71 \verb+\si{kA}+&

```

```

72     \SI{e3}{\A}\
73 \vsp
74 % \aa ngstr"om&
75 % length&
76 % \si{\AA}&
77 % \verb+\si{\AA}+&
78 % \SI{e-10}{\m}\
79 \vsp
80 arcminute&
81 plane angle&
82 \si{\arcmin}&
83 \verb+\si{\arcmin}+&
84 % Changed
85 % \SI{1/60}{\degree}\
86 % to
87 (1/60)\unit{\degree\nounit}\
88 arcsecond&
89 plane angle&
90 \si{\arcsec}&
91 \verb+\si{\arcsec}+&
92 % Changed
93 % \SI{1/60}{\arcmin}\
94 % to
95 (1/60)\unit{\arcmin\nounit}\
96 \vsp
97 astronomical unit&
98 length&
99 \si{\au}&
100 \verb+\si{\au}+&
101 mean earth to\newline sun distance\
102 \vsp
103 % From
104 % siunitx - A comprehensive (SI) units package
105 % Joseph Wright
106 % Released 2021-08-04
107 % (this describes v3.0.24, last revised 2021-08-04)
108 % https://mirror.las.iastate.edu/tex-archive/macros/latex/contrib/siunitx/siunitx.pdf
109 % page 51:
110 % ...the unit \atomicmassunit has similar deprecated status:
111 % this was listed as with experimentally-determined units
112 % in the 8th Edition of the si Brochure but is equivalent
113 % to the dalton, a unit which remains accepted.
114 % atomic mass unit&
115 % mass&
116 % \si{\amu}&
117 % \verb+\si{\amu}+&
118 % \SI{(1/12)}{mass of\newline carbon-12 atom}\
119 % \vsp
120 bar&
121 pressure&
122 \si{\bar}&
123 \verb+\si{\bar}+&
124 \SI{e-5}{\Pa}\
125 \quad millibar&
126 \ditto&
127 \si{\mbar}&
128 \verb+\si{\mbar}+&
129 \SI{e-3}{\bar}\
130 \vsp
131 barn&
132 area&
133 \si{\b}&
134 \verb+\si{\b}+&
135 \SI{e-28}{\m\squared}\

```

```

136 \vsp
137 becquerel&
138   radioactivity&
139   \si{\Bq}&
140   \verb+\si{\Bq}+&
141   one radioactive\newline decay per second\\
142 \vsp
143 bel&
144   sound intensity&
145   \si{\B}&
146   \verb+\si{\B}+&
147   10 decibels\\
148 \quad decibel&
149   \ditto&
150   \si{\dB}&
151   \verb+\si{\dB}+&
152   \SI{e-1}{\B}\\
153 \vsp
154 bohr&
155   length&
156   \si{\bohr}&
157   \verb+\si{\bohr}+&
158   distance between\newline nucleus and electron\newline in hydrogen atom\\
159 \vsp
160 bushel&
161   quantity&
162   \si{\bu}&
163   \verb+\si{\bu}+&
164   see \cite{wikipedia-bushel}\\
165 \vsp
166 candela&
167   luminous intensity&
168   \si{\cd}&
169   \verb+\si{\cd}+&
170   (SI base unit)\\
171 \vsp
172 coulomb&
173   electrical charge&
174   \si{\C}&
175   \verb+\si{\C}+&
176   \si{\A\per\s}\\
177 \vsp
178 dalton&
179   mass&
180   \si{\Da}&
181   \verb+\si{\Da}+&
182   another name for\newline atomic mass unit\\
183 \vsp
184 day&
185   time&
186   \si{\d}&
187   \verb+\si{\d}+&
188   \SI{86400}{\s}\\
189 \vsp
190 degree&
191   plane angle&
192   \si{\degree}&
193   \verb+\si{\degree}+&
194   1/360 of a cicle\\
195 \vsp
196 degree Celsius&
197   temperature&
198   \si{\celsius}&
199   \verb+\si{\celsius}+&

```

```

200     xxx\\
201 \vsp
202 electron mass&
203     mass&
204     \si{\em}&
205     \verb+\si{\em}+&
206     \SI{9.1093837139e-31}{\kg}\\
207 \vsp
208 electron volt&
209     energy&
210     \si{\eV}&
211     \verb+\si{\eV}+&
212     \SI{1.602176634e-19}{\joule}\\
213 \quad millielectronvolt&
214     \ditto&
215     \si{\meV}&
216     \verb+\si{\meV}+&
217     \SI{e-3}{\eV}\\
218 \quad kiloelectronvolt&
219     \ditto&
220     \si{\keV}&
221     \verb+\si{\keV}+&
222     \SI{e3}{\eV}\\
223 \quad megaelectronvolt&
224     \ditto&
225     \si{\MeV}&
226     \verb+\si{\MeV}+&
227     \SI{e6}{\eV}\\
228 \quad gigaelectronvolt&
229     \ditto&
230     \si{\GeV}&
231     \verb+\si{\GeV}+&
232     \SI{e9}{\eV}\\
233 \quad teraelectronvolt&
234     \ditto&
235     \si{\TeV}&
236     \verb+\si{\TeV}+&
237     \SI{e12}{\eV}\\
238 \vsp
239 elementary charge&
240     electrical charge&
241     \si{\ec}&
242     \verb+\si{\ec}+&
243     \href{https://en.wikipedia.org/wiki/Elementary_charge}{\SI{\approx 1.6e19}{\C}}\\
244 \vsp
245 farad&
246     electrical capacitance&
247     \si{\F}&
248     \verb+\si{\F}+&
249     \si{\s\tothe{4}\A\squared\per\m\squared\per\kg}\\
250 \quad femtofarad&
251     \ditto&
252     \si{\fF}&
253     \verb+\si{\fF}+&
254     \SI{e-15}{\F}\\
255 \quad picofarad&
256     \ditto&
257     \si{\pF}&
258     \verb+\si{\pF}+&
259     \SI{e-12}{\F}\\
260 \vsp
261 foot&
262     length&
263     \si{\ft}&

```

```

264     \verb+\si{ft}+&
265     \SI{0.3048}{m}\ % not an SI unit
266 \vsp
267 % gauss: The gauss, symbol G, sometimes Gs, is the cgs unit of measurement of magnetic flux.
268 gray&
269     absorbed dose of ionizing radiation&
270     \si{Gy}&
271     \verb+\si{Gy}+&
272     \si{J\per\kg}\
273 \vsp
274 hartree&
275     energy used in molecular orbital calculations&
276     \si{hartree}&
277     \verb+\si{hartree}+&
278     \SI{4.35974472221e-18}{joule}\
279 \vsp
280 hectare&
281     area&
282     \si{ha}&
283     \verb+\si{ha}+&
284     \SI{e4}{m\squared}\
285 \vsp
286 henry&
287     electrical inductance&
288     \si{H}&
289     \verb+\si{H}+&
290     \si{kg\m\squared\per\s\squared\per\A\squared}\
291 \vsp
292 hertz&
293     frequency&
294     \si{Hz}&
295     \verb+\si{Hz}+&
296     \si{\per\s}\
297 \quad millihertz&
298     \ditto&
299     \si{mHz}&
300     \verb+\si{mHz}+&
301     \SI{e-3}{Hz}\
302 \quad kilohertz&
303     \ditto&
304     \si{kHz}&
305     \verb+\si{kHz}+&
306     \SI{e3}{Hz}\
307 \quad megahertz&
308     \ditto&
309     \si{MHz}&
310     \verb+\si{MHz}+&
311     \SI{e6}{Hz}\
312 \quad gigahertz&
313     \ditto&
314     \si{GHz}&
315     \verb+\si{GHz}+&
316     \SI{e9}{Hz}\
317 \quad terahertz&
318     \ditto&
319     \si{THz}&
320     \verb+\si{THz}+&
321     \SI{e12}{Hz}\
322 \vsp
323 horsepower&
324     power&
325     \si{hp}&
326     \verb+\si{hp}+&
327     \SI{\approx 745.7}{W},

```



```

328     see \cite{wikipedia-horsepower} for details\\ % not an SI unit
329 \vsp
330 hour&
331     time&
332     \si{\h}&
333     \verb+\si{\h}+&
334     \SI{3600}{\s}\\
335 \vsp
336 inch&
337     length&
338     \si{\in}&
339     \verb+\si{\in}+&
340     \SI{25.4}{\mm}\\ % not an SI unit
341 \vsp
342 joule&
343     work or energy&
344     \si{\J}&
345     \verb+\si{\J}+&
346     \si{\kg\m\squared\per\s\squared}\\
347 \quad microjoule&
348     \ditto&
349     \si{\uJ}&
350     \verb+\si{\uJ}+&
351     \SI{e-6}{\J}\\
352 \quad millijoule&
353     \ditto&
354     \si{\mJ}&
355     \verb+\si{\mJ}+&
356     \SI{e-3}{\J}\\
357 \quad kilojoule&
358     \ditto&
359     \si{\kJ}&
360     \verb+\si{\kJ}+&
361     \SI{e3}{\J}\\
362 \quad megajoule&
363     \ditto&
364     \si{\MJ}&
365     \verb+\si{\MJ}+&
366     \SI{e6}{\J}\\
367 \vsp
368 katal&
369     catalytic activity&
370     \si{\kat}&
371     \verb+\si{\kat}+&
372     \si{\mol\per\s}\\
373 \vsp
374 kelvin&
375     thermodynamic temperature&
376     \si{\K}&
377     \verb+\si{\K}+&
378     (SI base unit)\\
379 \vsp
380 kilogram&
381     mass&
382     \si{\kg}&
383     \verb+\si{\kg}+&
384     (SI base unit)\\
385 \quad femtogram&
386     \ditto&
387     \si{\fg}&
388     \verb+\si{\fg}+&
389     \SI{e-15}{\g}\\
390 \quad picogram&
391     \ditto&

```

```

392     \si{pg}&
393     \verb+\si{pg}+&
394     \SI{e-12}{g}\
395 \quad nanogram&
396     \ditto&
397     \si{ng}&
398     \verb+\si{ng}+&
399     \SI{e-9}{g}\
400 \quad microgram&
401     \ditto&
402     \si{ug}&
403     \verb+\si{ug}+&
404     \SI{e-6}{g}\
405 \quad milligram&
406     \ditto&
407     \si{mg}&
408     \verb+\si{mg}+&
409     \SI{e-3}{g}\
410 \quad gram&
411     \ditto&
412     \si{g}&
413     \verb+\si{g}+&
414     \SI{e-3}{kg}\
415 \vsp
416 kilowatt hour&
417     electrical energy&
418     \si{kWh}&
419     \verb+\si{kWh}+&
420     \si{kWh}\
421 \vsp
422 knot&
423     speed&
424     \si{kn}&
425     \verb+\si{kn}+&
426     \si{M\per h}\
427 \vsp
428 liter&
429     volume&
430     \si{L}&
431     \verb+\si{L}+&
432     \SI{e-3}{m{cubed}}\
433 \quad microliter&
434     \ditto&
435     \si{uL}&
436     \verb+\si{uL}+&
437     \SI{e-6}{L}\
438 \quad milliliter&
439     \ditto&
440     \si{mL}&
441     \verb+\si{mL}+&
442     \SI{e-3}{L}\
443 \quad hectoliter&
444     \ditto&
445     \si{hL}&
446     \verb+\si{hL}+&
447     \SI{e2}{L}\
448 \vsp
449 lumen&
450     luminous flux&
451     \si{lm}&
452     \verb+\si{lm}+&
453     \si{cd\sr}\
454 \vsp
455 lux&

```

```

456     illumination&
457     \si{\lx}&
458     \verb+\si{\lx}+&
459     \si{\lm\per\m\squared}\\
460 \vsp
461 meter&
462     length&
463     \si{\m}&
464     \verb+\si{\m}+&
465     (SI base unit)\\
466 \quad picometer&
467     \ditto&
468     \si{\pm}&
469     \verb+\si{\pm}+&
470     \SI{e-12}{\m}\\
471 \quad nanometer&
472     \ditto&
473     \si{\nm}&
474     \verb+\si{\nm}+&
475     \SI{e-9}{\m}\\
476 \quad micrometer&
477     \ditto&
478     \si{\um}&
479     \verb+\si{\um}+&
480     \SI{e-6}{\m}\\
481 \quad millimeter&
482     \ditto&
483     \si{\mm}&
484     \verb+\si{\mm}+&
485     \SI{e-3}{\m}\\
486 \quad centimeter&
487     \ditto&
488     \si{\cm}&
489     \verb+\si{\cm}+&
490     \SI{e-2}{\m}\\
491 \quad decimeter&
492     \ditto&
493     \si{\dm}&
494     \verb+\si{\dm}+&
495     \SI{e-1}{\m}\\
496 \quad kilometer&
497     \ditto&
498     \si{\km}&
499     \verb+\si{\km}+&
500     \SI{e3}{\m}\\
501 \vsp
502 % mile: not an SI unit
503 millimeter of mercury&
504     pressure&
505     \si{\mmHg}&
506     \verb+\si{\mmHg}+&
507     \href{https://en.wikipedia.org/wiki/Millimetre_of_mercury}{\SI{\approx 133}{\Pa}}\\
508 \vsp
509 minute&
510     time&
511     \si{\min}&
512     \verb+\si{\min}+&
513     \SI{60}{\s}\\
514 \vsp
515 mole&
516     amount of substance&
517     \si{\mol}&
518     \verb+\si{\mol}+&
519     (SI base unit)\\

```

```

520 \quad femtomole&
521 \ditto&
522 \si{\fmol}&
523 \verb+\si{\fmol}+&
524 \SI{e-15}{\mol}\\
525 \quad picomole&
526 \ditto&
527 \si{\pmol}&
528 \verb+\si{\pmol}+&
529 \SI{e-12}{\mol}\\
530 \quad nanomole&
531 \ditto&
532 \si{\nmol}&
533 \verb+\si{\nmol}+&
534 \SI{e-9}{\mol}\\
535 \quad micromole&
536 \ditto&
537 \si{\umol}&
538 \verb+\si{\umol}+&
539 \SI{e-6}{\mol}\\
540 \quad millimole&
541 \ditto&
542 \si{\mmol}&
543 \verb+\si{\mmol}+&
544 \SI{e-3}{\mol}\\
545 \quad kilomole&
546 \ditto&
547 \si{\kmol}&
548 \verb+\si{\kmol}+&
549 \SI{e3}{\mol}\\
550 \vsp
551 nautical mile&
552 distance&
553 \si{\M}&
554 \verb+\si{\M}+&
555 \SI{1852}{\m}\\
556 \vsp
557 neper&
558 gain, loss, and relative values&
559 \si{\Np}&
560 \verb+\si{\Np}+&
561 1\\
562 \vsp
563 newton&
564 force&
565 \si{\N}&
566 \verb+\si{\N}+&
567 \si{\kg\m\per\s\squared}\\
568 \quad millinewton&
569 \ditto&
570 \si{\mN}&
571 \verb+\si{\mN}+&
572 \SI{e-3}{\N}\\
573 \quad kilonewton&
574 \ditto&
575 \si{\kN}&
576 \verb+\si{\kN}+&
577 \SI{e3}{\N}\\
578 \quad Meganewton&
579 \ditto&
580 \si{\MN}&
581 \verb+\si{\MN}+&
582 \SI{e6}{\N}\\
583 \vsp

```

```

584      ohm&
585      electrical resistance&
586      \si{\ohm}&
587      \verb+\si{\ohm}+&
588      \si{\kg\m\squared\per\s\cubed\per\A\squared}\
589      \quad milliohm&
590      \ditto&
591      \si{\mohm}&
592      \verb+\si{\mohm}+&
593      \SI{e-3}{ohm}\
594      \quad kiloohm&
595      \ditto&
596      \si{\kohm}&
597      \verb+\si{\kohm}+&
598      \SI{e3}{ohm}\
599      \quad megaohm&
600      \ditto&
601      \si{\Mohm}&
602      \verb+\si{\Mohm}+&
603      \SI{e6}{ohm}\
604      \vsp
605      pascal&
606      pressure&
607      \si{\Pa}&
608      \verb+\si{\Pa}+&
609      \si{\kg\per\m\per\s\squared}\
610      \quad kilopascal&
611      \ditto&
612      \si{\kPa}&
613      \verb+\si{\kPa}+&
614      \SI{e3}{\Pa}\
615      \quad megapascal&
616      \ditto&
617      \si{\MPa}&
618      \verb+\si{\MPa}+&
619      \SI{e6}{\Pa}\
620      \quad gigapascal&
621      \ditto&
622      \si{\GPa}&
623      \verb+\si{\GPa}+&
624      \SI{e9}{\Pa}\
625      \vsp
626      percent&
627      hundredths&
628      \si{\percent}&
629      \verb+\si{\percent}+&
630      \SI{e-2}{}\
631      \vsp
632      pound&
633      weight&
634      \si{\lb}&
635      \verb+\si{\lb}+&
636      \SI{.45359237}{\kg}\ % not an SI unit
637      \vsp
638      radian&
639      plane angular measurement&
640      \si{\rad}&
641      \verb+\si{\rad}+&
642      \((180/\pi)\ \unit{\degree\nounit}\
643      \vsp
644      reduced Planck constant&
645      angular momentum&
646      \si{\planckbar}&
647      \verb+\si{\planckbar}+&

```

```

648     \(\approx \SI{1.05e-34}{\J\s})\\
649 \vsp
650 second&
651     time&
652     \si{\s}&
653     \verb+\si{\s}+&
654     (SI base unit)\\
655 \quad attosecond&
656     \ditto&
657     \si{\as}&
658     \verb+\si{\as}+&
659     \SI{e-18}{\s}\\
660 \quad femtosecond&
661     \ditto&
662     \si{\fs}&
663     \verb+\si{\fs}+&
664     \SI{e-15}{\s}\\
665 \quad picosecond&
666     \ditto&
667     \si{\ps}&
668     \verb+\si{\ps}+&
669     \SI{e-12}{\s}\\
670 \quad nanosecond&
671     \ditto&
672     \si{\ns}&
673     \verb+\si{\ns}+&
674     \SI{e-9}{\s}\\
675 \quad microsecond&
676     \ditto&
677     \si{\us}&
678     \verb+\si{\us}+&
679     \SI{e-6}{\s}\\
680 \quad millisecond&
681     \ditto&
682     \si{\ms}&
683     \verb+\si{\ms}+&
684     \SI{e-3}{\s}\\
685 \vsp
686 siemens&
687     conductance&
688     \si{\S}&
689     \verb+\si{\S}+&
690     \si{\per\kg\per\m\squared\s\cubed\A\squared}\\
691 \vsp
692 sievert&
693     dosage of ionizing radiation&
694     \si{\Sv}&
695     \verb+\si{\Sv}+&
696     \si{\m\squared\per\s\squared}\\
697 \vsp
698 speed of light&
699     speed&
700     \si{\clight}&
701     \verb+\si{\clight}+&
702     \SI{299792458}{\m\per\s}\\
703 \vsp
704 standard deviation&
705     amount of variation&
706     \si{\SD}&
707     \verb+\si{\SD}+&
708     $\displaystyle \sqrt{\frac{1}{N-1} \sum_{i=1}^N (x_i - \bar{x})^2}$\\
709 \vsp
710 steradian&
711     measure of solid angles&

```

712       \si{sr}&  
713       \verb+\si{sr}+&  
714       \SI{1}{m\squared\per m\squared}\\  
715       \vsp  
716       tesla&  
717       magnetic flux density&  
718       \si{T}&  
719       \verb+\si{T}+&  
720       \si{kg\per s\squared\per A}\\  
721       \vsp  
722       metric ton&  
723       mass&  
724       \si{t}&  
725       \verb+\si{t}+&  
726       \SI{e3}{kg}\\  
727       \vsp  
728       volt&  
729       electrical potential difference&  
730       \si{V}&  
731       \verb+\si{V}+&  
732       \si{kg\m\squared\per s\cubed\per A}\\  
733       \quad picovolt&  
734       \ditto&  
735       \si{pV}&  
736       \verb+\si{pV}+&  
737       \SI{e-12}{V}\\  
738       \quad nanovolt&  
739       \ditto&  
740       \si{nV}&  
741       \verb+\si{nV}+&  
742       \SI{e-9}{V}\\  
743       \quad microvolt&  
744       \ditto&  
745       \si{uV}&  
746       \verb+\si{uV}+&  
747       \SI{e-6}{V}\\  
748       \quad millivolt&  
749       \ditto&  
750       \si{mV}&  
751       \verb+\si{mV}+&  
752       \SI{e-3}{V}\\  
753       \quad kilovolt&  
754       \ditto&  
755       \si{kV}&  
756       \verb+\si{kV}+&  
757       \SI{e3}{V}\\  
758       \vsp  
759       watt&  
760       power&  
761       \si{W}&  
762       \verb+\si{W}+&  
763       \si{kg\m\squared\per s\cubed}\\  
764       \quad microwatt&  
765       \ditto&  
766       \si{uW}&  
767       \verb+\si{uW}+&  
768       \SI{e-6}{W}\\  
769       \quad milliwatt&  
770       \ditto&  
771       \si{mW}&  
772       \verb+\si{mW}+&  
773       \SI{e-3}{W}\\  
774       \quad kilowatt&  
775       \ditto&

```

776     \si{\kW}&
777     \verb+\si{\kW}+&
778     \SI{e3}{\W}\
779     \quad megawatt&
780     \ditto&
781     \si{\MW}&
782     \verb+\si{\MW}+&
783     \SI{e6}{\W}\
784     \quad gigawatt&
785     \ditto&
786     \si{\GW}&
787     \verb+\si{\GW}+&
788     \SI{e9}{\W}\
789     \vsp
790     weber&
791     magnetic flux&
792     \si{\Wb}&
793     \verb+\si{\Wb}+&
794     \si{\kg\m\squared\per\s\squared\per\A}\
795     \vsp
796     yard&
797     length&
798     \si{\yd}&
799     \verb+\si{\yd}+&
800     \SI{.9144}{\m}\ % not an SI unit
801     \vsp
802     year&
803     time&
804     \si{\y}&
805     \verb+\si{\y}+&
806     \SI{\approx 365.25}{\d}\ % not an SI unit
807     \end{longtable}
808 }

```



## Q. RESOURCES

Books:

- *L<sup>A</sup>T<sub>E</sub>X Beginner’s Guide*, second edition, [75].

From the IEEE Author Center [76]

- The “IEEE Editorial Style Manual for Authors” [77] contains a formal set of editorial guidelines.
- “Editing Mathematics” [78] illustrates how to do mathematics.
- The IEEE Reference Guide [48] outlines how to cite references.

Colleges and Universities:

- IUPUI: *THESIS/DISSERTATION Formatting Guidelines & Deposit Procedures IUPUI* [79] is out-of-date. See *Thesis and Dissertation Office* [80].
- Purdue: *Thesis and Dissertation Office* [80]

Question and Answer site:

- T<sub>E</sub>X – L<sup>A</sup>T<sub>E</sub>X Stack Exchange is a question and answer site for users of T<sub>E</sub>X, L<sup>A</sup>T<sub>E</sub>X, and related typesetting systems [81].

```
1 \chapter{RESOURCES}
2
3 Books:
4 \begin{itemize}
5   \item
6     \citetitle{kottwitz2021}, second edition, \cite{kottwitz2021}.
7 \end{itemize}
8
9 \noindent
10 From the
11 IEEE Author Center
12 \cite{ieee-author-center}
13 \begin{itemize}
14   \item
15     The
16     \citetitle{ieee-editorial-style-manual-for-authors}
17     \cite{ieee-editorial-style-manual-for-authors}
18     contains a formal set of editorial guidelines.
19   \item
20     \citetitle{editing-mathematics}
21     \cite{editing-mathematics}
22     illustrates how to do mathematics.
23   \item
24     The
25     IEEE Reference Guide
26     \cite{ieee-reference-guide}
27     outlines how to cite references.
28 \end{itemize}
29
30 \noindent
31 Colleges and Universities:
```

```

32 \begin{itemize}
33   \item
34     IUPUI:
35     \citetitle{thesisdissertationiupui}
36     \cite{thesisdissertationiupui}
37     is out-of-date.
38     See
39     \citetitle{thesisanddissertationoffice}
40     \cite{thesisanddissertationoffice}.
41   \item
42     Purdue:
43     \citetitle{thesisanddissertationoffice}
44     \cite{thesisanddissertationoffice}
45 \end{itemize}
46
47 \noindent
48 Question and Answer site:
49 \begin{itemize}
50   \item
51     \TeX\ -- \LaTeX\ Stack Exchange
52     is a question and answer site
53     for users of
54     \TeX,
55     \LaTeX,
56     and related typesetting systems
57     \cite{tex-stackexchange}.
58 \end{itemize}

```

## R. TABLES

```
1 \chapter{TABLES}
2 \ix{table}
```

Here is a really simple table. I was greatly influenced by Herbert Voss' following ideas on typesetting tables [82]: Use `\toprule`, `\midrule`, and `\bottomrule`. Don't have blank horizontal space to the left or right of body of table.

**Table R.1.** The first three American Presidents.

Number	Name
1	George Washington
2	John Adams
3	Thomas Jefferson

```
1
2 Here is a really simple table.
3 I was greatly influenced
4 by Herbert Voss' following ideas
5 on typesetting tables
6 \cite{voss2011}:
7 Use \toprule, \midrule, and \bottomrule.
8 \index{\verb+\toprule+}
9 \index{\verb+\midrule+}
10 \index{\verb+\bottomrule+}
11 Don't have blank horizontal space to the left
12 or right of body of table.
13 \ix{Voss, Herbert}
14
15 % "h" means put table "here"---don't let it float to top or bottom of page
16 \begin{table}[ht]
17   \caption{The first three American Presidents.}
18   \vspace*{6pt}
19   \centering
20   % Table format:
21   %   WHAT   DESCRIPTION
22   %   @{}   don't put extra space before first column
23   %   r     right justify first column
24   %   l     left justify second column
25   %   @{}   don't put extra space after second column
26   \begin{tabular}{@{}rl@{}}
27     \toprule
28     \bf Number& \bf Name\\
29     \midrule
30     1& George Washington\\
31     2& John Adams\\
32     3& Thomas Jefferson\\
33     \bottomrule
34   \end{tabular}
35   \label{ta:first-three-american-presidents}
36 \end{table}
37 \ix{table}
38 \index{\verb+\begin{table}+}
```

Here is the same table with a longer caption.

**Table R.2.** The first three American Presidents. This caption is much, much, much, much, much, much, much, much, much, much longer.

Number	Name
1	George Washington
2	John Adams
3	Thomas Jefferson

```

1
2 \newpage
3
4 Here is the same table with a longer caption.
5
6 % "h" means put table "here"---don't let it float to top or bottom of page
7 \begin{table}[ht]
8   \caption{%
9     The first three American Presidents.
10    This caption is
11    much, much, much, much, much, much,
12    much, much, much, much, much, much
13    longer.%
14  }
15  \vspace*{6pt}
16  \centering
17  % Table format:
18  %   WHAT   DESCRIPTION
19  %   @{}    don't put extra space before first column
20  %   r      right justify first column
21  %   l      left justify second column
22  %   @{}    don't put extra space after second column
23  \begin{tabular}{@{}rl@{}}
24    \toprule
25    \bf Number& \bf Name\\
26    \midrule
27    1& George Washington\\
28    2& John Adams\\
29    3& Thomas Jefferson\\
30    \bottomrule
31  \end{tabular}
32  \label{ta:first-three-american-presidents-longer-caption}
33 \end{table}

```

$\LaTeX$  can print horizontal and vertical rules in tables. I don't like the way this looks and suggest you do not use tables with lots of horizontal and vertical lines.

**Table R.3.** The first three American Presidents with horizontal and vertical lines

#	Name
1	George Washington
2	John Adams
3	Thomas Jefferson

```

1
2 \newpage
3
4 \LaTeX\ can print horizontal
5 and vertical rules in tables.
6 I don't like the way this looks
7 and suggest you do not use tables
8 with lots of horizontal and vertical lines.
9 \begin{table}[ht]
10 \caption{The first three American Presidents with horizontal and vertical lines}
11 \vspace*{6pt}
12 \centering
13 % Table format:
14 % WHAT DESCRIPTION
15 % @{} don't put any space left of first column
16 % | print a vertical rule
17 % c center column
18 % | print a vertical rule
19 % l left justify column
20 % | print a vertical rule
21 % @{} don't put any space right of last column
22 \begin{tabular}{@{}|c|l|@{}}
23 % "\hline" prints a horizontal rule
24 \hline
25 \bf \#\& \bf Name\\
26 \hline
27 1& George Washington\\
28 \hline
29 2& John Adams\\
30 \hline
31 3& Thomas Jefferson\\
32 \hline
33 \end{tabular}
34 \label{ta:American-Presidents-with-horizontal}
35 \end{table}

```

Here is a more complicated table.

**Table R.4.** C Bitwise Operators

A	B	A B	A&B
0	0	0	0
0	1	1	0
1	0	1	0
1	1	1	1

```

1
2 \newpage
3
4 Here is a more complicated table.
5
6 {
7   \UndefineShortVerb{\|}
8   \begin{table}[ht]
9     \caption{C Bitwise Operators}
10    \vspace*{6pt}
11    \centering
12    % Table format:
13    %   WHAT      DESCRIPTION
14    %   @{}      don't put extra space before first column
15    %   c        first column is centered
16    %   c        second column is centered
17    %   c        third column is centered
18    %   c        fourth column is centered
19    %   @{}      don't put extra space after fourth column
20    \begin{tabular}{@{}cccc@{}}
21      \toprule
22      \bf A& \bf B& \bf A(|\B& \bf A&B\\[2pt]
23      \midrule
24      0& 0& 0& 0\\
25      0& 1& 1& 0\\
26      1& 0& 1& 0\\
27      1& 1& 1& 1\\
28      \bottomrule
29    \end{tabular}
30    \label{ta:C-Bitwise}
31  \end{table}
32 }

1 \begin{table}[ht]
2   \caption{Participant descriptors for twelve practitioners engaged in co-creation activities}
3   \label{tab:22participants}
4   \center
5   \begin{tabular}{@{}c11S@{}}
6     \toprule
7     \multicolumn{1}{@{}1}{\textbf{Pseudonym}}&
8     \textbf{Disciplinary Role}&
9     \textbf{Company Type}&
10    \multicolumn{1}{1@{}}{\textbf{\# Years of Experience}}\\
11    \midrule
12    \multicolumn{4}{@{}1@{}}%

```

**Table R.5.** Participant descriptors for twelve practitioners engaged in co-creation activities

Pseudonym	Disciplinary Role	Company Type	# Years of Experience
<b>Sequence 1:</b> A1.1 → B2.1: Overlapping dilemma cards to strengthen and represent ethical complexity through practitioner’s current ecological complexity model			
1P1	UX Designer	Enterprise (B2C)	1.5
1P2	Product Manager	Enterprise (B2B)	5
1P3	Data Scientist	Agency or Consultancy	1
<b>Sequence 2:</b> B2.1 → A1.1: Building and tracing complexity based on Dilemmas Cards to reconstruct and reflect on their experience			
2P1	UX Designer	Agency or Consultancy	8
2P2	Product Manager	Agency or Consultancy	2
2P3	Software Engineer	Enterprise (B2B)	2

```

13      {%
14      \textbf{Sequence 1:} $\text{A1.1}\to\text{B2.1}$:
15      Overlapping dilemma cards to strengthen and represent%
16      }\
17      \multicolumn{4}{@{}1}{ethical complexity
18      through practitioner’s current ecological complexity model}\
19      1P1& UX Designer& Enterprise (B2C)& 1.5\
20      1P2& Product Manager& Enterprise (B2B)& 5\
21      1P3& Data Scientist& Agency or Consultancy& 1\
22      \noalign{\vspace{8pt}}
23      \multicolumn{4}{@{}1@{}}%
24      {%
25      \textbf{Sequence 2:} $\text{B2.1}\to\text{A1.1}$:
26      Building and tracing complexity based on Dilemmas Cards%
27      }\
28      \multicolumn{4}{@{}1}{to reconstruct and reflect on their experience}\
29      2P1& UX Designer& Agency or Consultancy& 8\
30      2P2& Product Manager& Agency or Consultancy& 2\
31      2P3& Software Engineer& Enterprise (B2B)& 2\
32      \bottomrule
33      \end{tabular}
34      \end{table}

```

Here is a table that is too long to fit on one page.

**Table R.6.** State Abbreviations

<b>State</b>	<b>Abbreviation</b>
Alabama	AL
Alaska	AK
American Samoa	AS
Arizona	AZ
Arkansas	AR
Armed Forces Europe	AE
Armed Forces Pacific	AP
Armed Forces the Americas	AA
California	CA
Colorado	CO
Connecticut	CT
Delaware	DE
District of Columbia	DC
Federated States of Micronesia	FM
Florida	FL
Georgia	GA
Guam	GU
Hawaii	HI
Idaho	ID
Illinois	IL
Indiana	IN
Iowa	IA
Kansas	KS
Kentucky	KY
Louisiana	LA
Maine	ME
Marshall Islands	MH
Maryland	MD
Massachusetts	MA
Michigan	MI
Minnesota	MN
Mississippi	MS
Missouri	MO
Montana	MT
Nebraska	NE
Nevada	NV
New Hampshire	NH
New Jersey	NJ
New Mexico	NM

*continued on next page*







34 Connecticut& CT\\  
35 Delaware& DE\\  
36 District of Columbia& DC\\  
37 Federated States of Micronesia& FM\\  
38 Florida& FL\\  
39 Georgia& GA\\  
40 Guam& GU\\  
41 Hawaii& HI\\  
42 Idaho& ID\\  
43 Illinois& IL\\  
44 Indiana& IN\\  
45 Iowa& IA\\  
46 Kansas& KS\\  
47 Kentucky& KY\\  
48 Louisiana& LA\\  
49 Maine& ME\\  
50 Marshall Islands& MH\\  
51 Maryland& MD\\  
52 Massachusetts& MA\\  
53 Michigan& MI\\  
54 Minnesota& MN\\  
55 Mississippi& MS\\  
56 Missouri& MO\\  
57 Montana& MT\\  
58 Nebraska& NE\\  
59 Nevada& NV\\  
60 New Hampshire& NH\\  
61 New Jersey& NJ\\  
62 New Mexico& NM\\  
63 New York& NY\\  
64 North Carolina& NC\\  
65 North Dakota& ND\\  
66 Northern Mariana Islands& MP\\  
67 Ohio& OH\\  
68 Oklahoma& OK\\  
69 Oregon& OR\\  
70 Pennsylvania& PA\\  
71 Puerto Rico& PR\\  
72 Rhode Island& RI\\  
73 South Carolina& SC\\  
74 South Dakota& SD\\  
75 Tennessee& TN\\  
76 Texas& TX\\  
77 Utah& UT\\  
78 Vermont& VT\\  
79 Virgin Islands& VI\\  
80 Virginia& VA\\  
81 Washington& WA\\  
82 West Virginia& WV\\  
83 Wisconsin& WI\\  
84 Wyoming& WY\\  
85 \multicolumn{2}{c}{make this three pages long}\\  
86 \multicolumn{2}{c}{make this three pages long}\\  
87 \multicolumn{2}{c}{make this three pages long}\\  
88 \multicolumn{2}{c}{make this three pages long}\\  
89 \multicolumn{2}{c}{make this three pages long}\\  
90 \multicolumn{2}{c}{make this three pages long}\\  
91 \multicolumn{2}{c}{make this three pages long}\\  
92 \multicolumn{2}{c}{make this three pages long}\\  
93 \multicolumn{2}{c}{make this three pages long}\\  
94 \multicolumn{2}{c}{make this three pages long}\\  
95 \multicolumn{2}{c}{make this three pages long}\\  
96 \multicolumn{2}{c}{make this three pages long}\\  
97 \multicolumn{2}{c}{make this three pages long}

```
98 \multicolumn{2}{c}{make this three pages long}\\
99 \multicolumn{2}{c}{make this three pages long}\\
100 \multicolumn{2}{c}{make this three pages long}\\
101 \multicolumn{2}{c}{make this three pages long}\\
102 \multicolumn{2}{c}{make this three pages long}\\
103 \multicolumn{2}{c}{make this three pages long}\\
104 \multicolumn{2}{c}{make this three pages long}\\
105 \multicolumn{2}{c}{make this three pages long}\\
106 \multicolumn{2}{c}{make this three pages long}\\
107 \multicolumn{2}{c}{make this three pages long}\\
108 \multicolumn{2}{c}{make this three pages long}\\
109 \multicolumn{2}{c}{make this three pages long}\\
110 \multicolumn{2}{c}{make this three pages long}\\
111 \multicolumn{2}{c}{make this three pages long}\\
112 \multicolumn{2}{c}{make this three pages long}\\
113 \multicolumn{2}{c}{make this three pages long}\\
114 \multicolumn{2}{c}{make this three pages long}\\
115 \multicolumn{2}{c}{make this three pages long}\\
116 \multicolumn{2}{c}{make this three pages long}\\
117 \multicolumn{2}{c}{make this three pages long}\\
118 \multicolumn{2}{c}{make this three pages long}\\
119 \multicolumn{2}{c}{make this three pages long}\\
120 \end{longtable}
```

```

1
2 % The table is on the next page.
3
4 \newpage
5
6 % Set \LTcapwidth (the longtable caption width)
7 % to \textwidth minus 4 paragraph indent widths.
8 \setlength{\LTcapwidth}{\textwidth}
9 \addtolength{\LTcapwidth}{-4\parindent}
10
11 \newlength{\twidth}
12 \newlength{\theight}
13
14 \setlength{\twidth}{\textwidth}
15 \setlength{\theight}{\textheight}
16
17 \begin{sidewaystable}
18 % The following two lines compensate for what I think is a bug.
19 \setlength{\textwidth}{\theight}
20 \setlength{\textheight}{\twidth}
21 \caption{Sidewaystable of the first three American Presidents.}
22 \vspace*{6pt}
23 \centering
24 \begin{tabular}{@{}rl@{}}
25 \toprule
26 \bf Number& \bf Name\\
27 \midrule
28 1& George Washington\\
29 2& John Adams\\
30 3& Thomas Jefferson\\
31 \bottomrule
32 \end{tabular}
33 \end{sidewaystable}

```

**Table R.7.** Sidewaystable of the first three American Presidents.

<b>Number</b>	<b>Name</b>
1	George Washington
2	John Adams
3	Thomas Jefferson

```

1 \begin{sidewaystable}
2   % The following two lines compensate for what I think is a bug.
3   \setlength{\textwidth}{\theight}
4   \setlength{\textheight}{\twidth}
5   \caption{Two tables can be placed vertically in a sidewaysstable environment.}
6   \vspace*{6pt}
7   \centering
8   \begin{tabular}{@{}rl@{}}
9     \toprule
10    \bf Number& \bf Name\\
11    \midrule
12    1& George Washington\\
13    2& John Adams\\
14    3& Thomas Jefferson\\
15    \bottomrule
16  \end{tabular}
17  \vspace*{2\baselineskip}
18  \caption{This is the second table in the sideways environment.}
19  \vspace*{6pt}
20  \begin{tabular}{@{}rl@{}}
21    \toprule
22    \bf Number& \bf Name\\
23    \midrule
24    1& George Washington\\
25    2& John Adams\\
26    3& Thomas Jefferson\\
27    \bottomrule
28  \end{tabular}
29 \end{sidewaystable}

```

**Table R.8.** Two tables can be placed vertically in a sidewaysstable environment.

<b>Number</b>	<b>Name</b>
1	George Washington
2	John Adams
3	Thomas Jefferson

**Table R.9.** This is the second table in the sideways environment.

<b>Number</b>	<b>Name</b>
1	George Washington
2	John Adams
3	Thomas Jefferson



```

1 \begin{sidewaystable}[ht]%
2 % The following two lines compensate for what I think is a bug.
3 \setlength{\textwidth}{\theight}%
4 \setlength{\textheight}{\twidth}%
5 \caption{Live Guitar Open String Testing Data - Pitch (\textit{f\textsubscript{0}})}
6 \vspace*{6pt}%
7 \label{ta:live-guitar}%
8 % Define "Live Guitar Test" column.
9 \def\lgt#1{\bf Live Guitar Test #1}
10 % Define "Note", "Computed", "Measured", "%", and "Accuracy" column headings.
11 \def\note{\bf Note}
12 \def\cal{\bf Computed}
13 \def\mea{\bf Measured}
14 \def\per{\bf \%}
15 \def\acc{\bf Accuracy}
16 % Define "Name", "f_0 (Hz)", "Error", and "Range (\textcent)" column headings.
17 \def\name{\bf Name}
18 \def\fsz{\bf \textit{f\textsubscript{0}} (Hz)}
19 \def\err{\bf Error}
20 \def\ran{\bf Range (\textcent)}
21 % Make "!" be an invisible character the width of a digit.
22 % (All digits in the normal font are the same width.)
23 \catcode'\!=\active \def!\{\hphantom 1}
24 \hbox to \textwidth
25 {%
26 \hss
27 % From http://zerocapcable.com/?page_id=225
28 % The units of tuning accuracy are cents. A cent is one hundredth
29 % of a semitone. Since there are 12 semitones in an octave, there
30 % are 1200 cents in an octave.
31 % The default \tabcolsep is 6.0pt.
32 \setlength{\tabcolsep}{5pt}%
33 \begin{tabular}{@{}cc|ccc|ccc|ccc@{}}
34 \hline
35 \multicolumn{2}{c|}{ }&
36 \multicolumn{3}{c|}{\lgt1}&
37 \multicolumn{3}{c|}{\lgt2}&
38 \multicolumn{3}{c|}{\lgt3}\
39 \cline{3-11}
40 \note& \cal& \mea& \per& \acc& \mea& \per& \acc& \mea& \per& \acc\
41 \name& \fsz& \fsz& \err& \ran& \fsz& \err& \ran& \fsz& \err& \ran\
42 \hline
43 E\textsubscript 2& !82.407& !82.333& 0.0897& $+2$& !82.616& 0.2538& $+6$& !82.474& 0.0814& $+2$\\
44 A\textsubscript 2& 110.000& 110.092& 0.0836& $+2$& 110.092& 0.0836& $+2$& 110.092& 0.0836& $+2$\\
45 D\textsubscript 3& 146.832& 146.789& 0.0295& $-2$& 146.789& 0.0295& $-2$& 147.239& 0.2769& $+6$\\
46 G\textsubscript 3& 195.998& 196.721& 0.3690& $+8$& 195.918& 0.0407& $+2$& 196.721& 0.3690& $+8$\\
47 B\textsubscript 3& 246.942& 247.423& 0.1949& $+4$& 246.517& 0.1720& $-4$& 247.423& 0.1949& $+4$\\
48 E\textsubscript 4& 329.628& 331.034& 0.4267& $+8$& 331.034& 0.4267& $+8$& 331.034& 0.4267& $+8$\\
49 \hline
50 \multicolumn{11}{@{}l}{Thanks to Kathryn Schmidt for donating this table.}\
51 \end{tabular}
52 \hss
53 }
54 \end{sidewaystable}

```

**Table R.10.** Live Guitar Open String Testing Data - Pitch ( $f_0$ )

Note Name	Computed $f_0$ (Hz)	Live Guitar Test 1			Live Guitar Test 2			Live Guitar Test 3		
		Measured $f_0$ (Hz)	% Error	Accuracy Range	Measured $f_0$ (Hz)	% Error	Accuracy Range	Measured $f_0$ (Hz)	% Error	Accuracy Range
E <sub>2</sub>	82.407	82.333	0.0897	+2	82.616	0.2538	+6	82.474	0.0814	+2
A <sub>2</sub>	110.000	110.092	0.0836	+2	110.092	0.0836	+2	110.092	0.0836	+2
D <sub>3</sub>	146.832	146.789	0.0295	-2	146.789	0.0295	-2	147.239	0.2769	+6
G <sub>3</sub>	195.998	196.721	0.3690	+8	195.918	0.0407	+2	196.721	0.3690	+8
B <sub>3</sub>	246.942	247.423	0.1949	+4	246.517	0.1720	-4	247.423	0.1949	+4
E <sub>4</sub>	329.628	331.034	0.4267	+8	331.034	0.4267	+8	331.034	0.4267	+8

Thanks to Kathryn Schmidt for donating this table.

```

1 % Define a control sequence to save typing.
2 % Let * represent zero or more spaces!
3 % Method 1: \def\g#1{ requires using \g*{10} for 10.
4 %           Two shifted characters, { and } are needed.
5 % Method 2: \def\g#1/{ requires using \g*10/ for 10.
6 %           One unshifted character, / is needed.
7 % Method 2 requires less work than Method 1.
8 \def\g#1/{\includegraphics[scale=0.5]{gr-metapost-tally-#1.pdf}}%
9
10 % Define a length for use later.
11 \newlength{\tlen}
12 \setlength{\tlen}{2\parindent}

```

**Table R.11.** First tally table. Use this method. I think it is the simplest.

```

1 \begin{table}[ht]%
2 \label{ta:first-tally-table}
3 \caption
4 [%
5 First tally table. Use this method.%
6 ]%
7 {%
8 First tally table. Use this method. I think it is the simplest.
9 }
10 \vspace*{6pt}
11 % Note that tabular* instead of tabular is used below.
12 % The {\textwidth} makes the total width of the table the width
13 % of the printed area of the page.
14 % The @{\kern\tlen} puts blank space the width of two paragraph indents
15 % before the first column.
16 % The @{\extracolsep{\fill}} adds \fill space between all subsequent
17 % columns.
18 % The lll left justifies the next three columns.
19 % after the column.
20 % The @{\kern\tlen} puts blank space the width of two
21 % paragraph indents before the first column.
22 \begin{tabular*}{\textwidth}{@{\kern\tlen}@{\extracolsep{\fill}}lll@{\kern\tlen}}%
23 \g 01/& \g 02/& \g 03/\
24 \g 04/& \g 05/\
25 \end{tabular*}%
26 \end{table}

```

**Table R.12.** Second tally table. Don't use this method. The method used in the first tally table is easier to understand.

```

1 \begin{table}[ht]
2 \caption{
3 Second tally table.
4 Don't use this method.
5 The method used in the first tally table
6 is easier to understand.%
7 }%
8 \vspace*{6pt}
9 % Note that tabularx instead of tabular is used below.
10 % The {\textwidth} makes the total width of the table the width
11 % of the printed area on the page.
12 % The @{\kern\tlen} puts blank space the width of two paragraph indents
13 % before the first column.
14 % The XX makes the first two columns the same width including the space
15 % after the column.
16 % The l left justifies the last column.
17 % The @{\kern\tlen} puts blank space the width of two paragraph indents
18 % after the last column.
19 \begin{tabularx}{\textwidth}{@{\kern\tlen}XXl@{\kern\tlen}}%
20 \g 01/& \g 02/& \g 03/\
21 \g 04/& \g 05/\
22 \end{tabularx}%
23 \end{table}

```

**Table R.13.** Third tally table. Don't use this method. The method used in the first tally table is easier to understand.



```

1 \begin{table}[h!]
2 \caption{
3 Third tally table.
4 Don't use this method.
5 The method used in the first tally table
6 is easier to understand.%
7 }%
8 \vspace*{6pt}
9 \def\t #1/#2/#3/%
10 {%
11 \hbox to\textwidth{%
12 \kern\tlen \g #1/\hfil \g #2/\hfil \g #3/\kern\tlen
13 }%
14 }%
15 \vbox{
16 \t 01/02/03/
17 \hbox to\textwidth{%
18 \kern\tlen \g 04/\hfil \g 05/\hfil \phantom{\g 05/}\kern\tlen
19 }%
20 }
21 \end{table}

```

```

1
2
3 % Process all unprocessed floats.
4 % None of the current floats will be after the \FloatBarrier.
5 \FloatBarrier

```

## S. SPECIAL CHARACTERS

```

1 \chapter{SPECIAL CHARACTERS}
2 \ix{special characters//Special Characters appendix}

```

Symbol	L <sup>A</sup> T <sub>E</sub> X Input	Comment
¡	<code>\textexclamdown</code>	inverted exclamation mark ! ' also works in PurdueThesis
¿	<code>\textquestiondown</code>	inverted question mark ? ' also works in PurdueThesis
ő	<code>\H{o}</code>	Hungarian o with double acute

```

1 % The following two lines compensate for what I think is a bug.
2 \begin{tabular}{@{}l|l|l@{}}
3 \toprule
4 \textbf{Symbol} & \textbf{\LaTeX\ Input}& \textbf{Comment}\\
5 \midrule
6 \textexclamdown & |\textexclamdown| & & inverted exclamation mark\\
7 & & & |!'| also works in PurdueThesis\\
8 \textquestiondown& |\textquestiondown| & & inverted question mark\\
9 & & & |?'| also works in PurdueThesis\\
10 \H{o} & & |\H{o}| & Hungarian o with double acute\\
11 \bottomrule
12 \end{tabular}
13 \index{special characters}
14 \index{\verb+\begin{tabular}+}

```

# T. TESTING (THIS APPENDIX IS USED FOR TESTING, DOES THIS VERY, VERY, VERY, VERY, VERY, VERY, VERY, VERY, VERY, VERY, VERY, VERY, VERY, VERY, VERY, LONG TITLE LOOK OK?)

## T.1 Apostrophes

Test apostrophes in text mode:  $f'$ ,  $f''$ , and  $f'''$ .

Test apostrophes in math mode:  $f'$ ,  $f''$ , and  $f'''$ .

```
1
2
3 \section{Apostrophes}
4
5 Test apostrophes in text mode:  $f'$ ,  $f''$ , and  $f'''$ .
6
7 Test apostrophes in math mode:  $(f', f'', \text{ and } f''')$ .
```

## T.2 Cite long title

Cite a reference with a very, very, very, ... long title [83].

```
1
2
3 \section{Cite long title}
4
5 Cite a reference with a very, very, very, \ldots\ long title
6 \cite{test-long-title}.
7
```

## T.3 Footnote

This is a footnote<sup>1</sup>

```
1
2
3 \section{Footnote}
4
5 This is a footnote\footnote{This is a footnote.}%
6 \index{\verb+\footnote+}%
7 \ix{footnote}
```

---

<sup>1</sup>↑This is a footnote.

## T.4 PurdueThesis Logo

Input	Output	Comment
PurdueThesis	PurdueThesis	just ordinary text
\PurdueThesisLogo	PurdueThesis	PurdueThesis logo, less space between P–u, e–T, and T–h
PuTh	PuTh	just ordinary text
\PuThLogo	PuTh	PuTh abbreviation logo, less space between P–u, u–T, and T–h

```

1
2
3 \section{\PurdueThesisLogo\ Logo}
4
5 \begin{tabular}{@{}l|l|l@{}}
6 \bfseries Input& \bfseries Output& \bfseries Comment\\
7 |PurdueThesis|& PurdueThesis& just ordinary text\\
8 |\PurdueThesisLogo|& \PurdueThesisLogo& PurdueThesis logo, less space between\\
9 & & & |P|--|u|, |e|--|T|, and |T|--|h|\\
10 |PuTh|& PuTh& just ordinary text\\
11 |\PuThLogo|& \PuThLogo& PuTh abbreviation logo, less space between\\
12 & & & |P|--|u|, |u|--|T|, and |T|--|h|\\
13 \end{tabular}

```

## T.5 Section headings with SmallCaps font

Section headings with `{\protect\scshape SmallCaps}` don't work.

This does not work:

```
\section{Section with {\protect\scshape SmallCaps}}
```

use

```

\section
  [Section with {\protect\scshape SmallCaps}]%
  {Section with S{\protect\scriptsize MALL}C{\protect\scriptsize APS}}

```

instead.

```

1
2
3 \section{Section headings with {\protect\scshape SmallCaps} font}
4 \label{section-headings-with-smallcaps-font}
5
6 Section headings with |{\protect\scshape SmallCaps}| don't work.%
7 \todoerror{Section headings with {\protect\scshape SmallCaps} don't work.}
8
9 \mbox{}
10
11 \todowarn{Putting this section in a VerbatimOut environment
12   caused a ‘‘! LaTeX Error: Float(s) lost.’’ error.}
13
14 This does not work:

```

```

15 \begin{verbatim}
16   \section{Section with {\protect\scshape SmallCaps}}
17 \end{verbatim}
18 use
19 \begin{verbatim}
20   \section
21     [Section with {\protect\scshape SmallCaps}]%
22     {Section with S{\protect\scriptsize MALL}C{\protect\scriptsize APS}}
23 \end{verbatim}
24 instead.

```

## T.6 To-do notes

Make a todo comment.

The Purdue football game is at noon tomorrow.

$$\sum_1^n = 1 + 2 + \cdots + n - 1$$

```

1
2
3 \section{To-do notes}
4
5 Make a todo comment.%
6 \todocomment{Some people use ‘‘to-do’’, but I want to be consistent with command names.}
7
8 The Purdue football game is at noon tomorrow.%
9 \todowarn{Leave at 10:00---the traffic will be terrible.}
10
11 \[
12   \sum_1^n = 1 + 2 + \cdots + n - 1
13 \]%
14 \todoerror{\(n-1\) should be \((n)\).}

```

These lower-case Greek characters should be used in math mode:

$\alpha$ \alpha	$\beta$ \beta	$\gamma$ \gamma	$\delta$ \delta	$\epsilon$ \epsilon	$\zeta$ \zeta
$\eta$ \eta	$\theta$ \theta	$\iota$ \iota	$\kappa$ \kappa	$\lambda$ \lambda	$\mu$ \mu
$\nu$ \nu	$\xi$ \xi	$\omicron$ \omicron	$\pi$ \pi	$\rho$ \rho	$\sigma$ \sigma
$\tau$ \tau	$\upsilon$ \upsilon	$\phi$ \phi	$\chi$ \chi	$\psi$ \psi	$\omega$ \omega

## T.7 Figure Captions

This is a paragraph.

```

1
2 \paragraph{This is a paragraph.}

1
2 \begin{figure}[ht]
3   \centering

```



This is the figure.

**Figure T.1.** This is the long caption. This is the long caption. This is the long caption. This is the long caption. This is the long caption. This is the long caption. This is the long caption. This is the long caption. This is the long caption.

```
4     This is the figure.
5     \caption[A short caption for the list of figures.]{%
6     This is the long caption. This is the long caption.
7     This is the long caption. This is the long caption.
8     This is the long caption. This is the long caption.
9     This is the long caption. This is the long caption.%
10    }
11    \end{figure}
```

## U. TEXT

```
1 \chapter{TEXT}
2
3 \ix{Text appendix}
```

### U.1 Color

The soul package [84] package is loaded by `thesis.tex`. The package defines the following commands: `this text is highlighted in yellow and is so long it is absolutely guaranteed to go to the next line` for testing. See the citation for much more information.

The xcolor package [85] package is loaded by `PurdueThesis`. The package defines the following commands: `this text is printed in red and is so long it is absolutely guaranteed to go to the next line` for testing. See the citation for much more information.

```
1
2
3 \section{Color}
4
5 The soul package \cite{franz2003} package is loaded by |thesis.tex|.
6 The package defines the following commands:
7 \hl{%
8   this text is highlighted in yellow
9   and is so long it is absolutely guaranteed
10  to go to the next line%
11 } for testing.
12 See the citation for much more information.
13
14 The xcolor package \cite{kern2021} package is loaded by \PurdueThesisLogo.
15 The package defines the following commands:
16 \textcolor{red}{%
17   this text is printed in red
18   and is so long it is absolutely guaranteed
19   to go to the next line%
20 } for testing.
21 See the citation for much more information.
```

### U.2 Description, enumerate, and itemize environments

The first example:

**elephant** This is the elephant item of a description environment. This is the elephant item of a description environment. This is the elephant item of a description environment.

**frog** This is the frog item of a description environment. This is the frog item of a description environment. This is the frog item of a description environment.

1. This is the first item of an enumerate environment. This is the first item of an enumerate environment. This is the first item of an enumerate environment.
2. This is the second item of an enumerate environment. This is the second item of an enumerate environment. This is the second item of an enumerate environment.

- This is the first item of an itemize environment. This is the first item of an itemize environment. This is the first item of an itemize environment.
- This is the second item of an itemize environment. This is the second item of an itemize environment. This is the second item of an itemize environment.

```

1
2 % The \sentence command is also defined in the convington package
3 % so I'll comment this one out. I don't think this sentence
4 % command is used.
5 % \newcommand\sentence[1]{\MyRepeat{This is a sentence. }{#1}}
6
7 \section{Description, enumerate, and itemize environments}
8 \ix{description environment//enumerate environment//itemize environment}
9 \index{\verb+\begin{description}+}
10 \index{\verb+\begin{enumerate}+}
11 \index{\verb+\begin{itemize}+}
12
13 The first example:
14
15 \begin{description}
16   \item[elephant]
17     \MyRepeat{This is the elephant item of a description environment. }{3}
18   \item[frog]
19     \MyRepeat{This is the frog item of a description environment. }{3}
20 \end{description}
21
22 \begin{enumerate}
23   \item
24     \MyRepeat{This is the first item of an enumerate environment. }{3}
25   \item
26     \MyRepeat{This is the second item of an enumerate environment. }{3}
27 \end{enumerate}
28
29 \begin{itemize}
30   \item
31     \MyRepeat{This is the first item of an itemize environment. }{3}
32   \item
33     \MyRepeat{This is the second item of an itemize environment. }{3}
34 \end{itemize}

```

The second example:

**elephant** This is the elephant item of a level zero description environment. This is the elephant item of a level zero description environment.

1. This is the first item of a level one enumerate environment. This is the first item of a level one enumerate environment.
  - This is the first item of a level two itemize environment. This is the first item of a level two itemize environment.
  - This is the first item of a level two itemize environment. This is the first item of a level two itemize environment.
2. This is the second item of a level one enumerate environment. This is the second item of a level one enumerate environment.

**frog** This is the frog item of a level zero description environment. This is the frog item of a level zero description environment.

```
1 The second example:
2
3 \begin{description}
4   \item[elephant]
5     \MyRepeat{This is the elephant item of a level zero description environment. }{2}
6   \begin{enumerate}
7     \item
8       \MyRepeat{This is the first item of a level one enumerate environment. }{2}
9     \begin{itemize}
10      \item
11        \MyRepeat{This is the first item of a level two itemize environment. }{2}
12      \item
13        \MyRepeat{This is the first item of a level two itemize environment. }{2}
14      \end{itemize}
15    \item
16      \MyRepeat{This is the second item of a level one enumerate environment. }{2}
17    \end{enumerate}
18   \item[frog]
19     \MyRepeat{This is the frog item of a level zero description environment. }{2}
20 \end{description}
```

### U.3 Computer program listings

```
1
2
3 \section{Computer program listings}
4
5 \lstset{language=Pascal}
6
7 \begin{ZZlisting}
8   \caption{This is the caption.}
9   \begin{CenteredBox}
10    This is the listing.
11   \end{CenteredBox}
12 \end{ZZlisting}
```

**Listing U.1.** This is the caption.  
This is the listing.

**Listing U.2.** A Pascal Program

```
for i:=maxint to 0 do
begin
  { do nothing }
end;
Write( 'Case□insensitive. ');
Write( 'Pascal□keywords. ');
```

```

13
14 \begin{ZZlisting}
15   \caption{A Pascal Program}
16   \begin{CenteredBox}
17     \begin{lstlisting}
18     for i:=maxint to 0 do
19     begin
20       { do nothing }
21     end;
22     Write('Case insensitive. ');
23     WriteE('Pascal keywords. ');
24     \end{lstlisting}
25   \end{CenteredBox}
26 \end{ZZlisting}

```

## U.4 Frenchspacing

DON'T USE THIS: As far as I know I'm the only one that uses this crazy format. The `\frenchspacing` command puts approximately  $\frac{\text{one}}{\text{two}}$  spaces after sentences. The default is `\nonfrenchspacing`.

BETTER [86]: The `\frenchspacing` (`\nonfrenchspacing`) command puts approximately one (two) spaces after sentences. The default is `\nonfrenchspacing`.

BEST [87]: The `\frenchspacing`/`\nonfrenchspacing` command puts approximately one/two spaces after sentences. The default is `\nonfrenchspacing`.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam cursus. Morbi ut mi. Nullam enim leo, egestas id, condimentum at, laoreet mattis, massa. Sed eleifend nonummy diam. Praesent mauris ante, elementum et, bibendum at, posuere sit amet, nibh. Duis tincidunt lectus quis dui viverra vestibulum. Suspendisse vulputate aliquam dui. Nulla elementum dui ut augue. Aliquam vehicula mi at mauris. Maecenas placerat, nisl at consequat rhoncus, sem nunc gravida justo, quis eleifend arcu velit quis lacus. Morbi magna magna, tincidunt a, mattis non, imperdiet vitae, tellus. Sed odio est, auctor ac, sollicitudin in, consequat vitae, orci. Fusce id felis. Vivamus sollicitudin metus eget eros.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam cursus. Morbi ut mi. Nullam enim leo, egestas id, condimentum at, laoreet mattis, massa. Sed eleifend nonummy diam. Praesent mauris ante, elementum et, bibendum at, posuere sit amet, nibh. Duis tincidunt lectus quis dui viverra vestibulum. Suspendisse vulputate aliquam dui. Nulla elementum dui ut augue. Aliquam vehicula mi at mauris. Maecenas placerat, nisl at consequat rhoncus, sem nunc gravida justo, quis eleifend arcu velit quis lacus. Morbi magna magna, tincidunt a, mattis non, imperdiet vitae, tellus. Sed odio est, auctor ac, sollicitudin in, consequat vitae, orci. Fusce id felis. Vivamus sollicitudin metus eget eros.

```

1
2
3 \section{Frenchspacing}%
4 \ix{frenchspacing//nonfrenchspacing}
5 \index{\verb+\frenchspacing+}
6 \index{\verb+\nonfrenchspacing+}
7
8 {\small DON'T USE THIS:}
9 As far as I know I'm the only one

```

```

10 that uses this crazy format.
11 The
12 \def\t{{\tt\char'134 frenchspacing}}
13 \def\u{{\tt\char'134 nonfrenchspacing}}
14 \raise6pt\hbox{\rlap{\t}}%
15 \lower6pt\hbox{\u}
16 command puts approximately
17 \raise6pt\hbox{\rlap{one}}%
18 \lower6pt\hbox{two}
19 spaces after sentences.
20 The default\[\[2pt]
21 is |\nonfrenchspacing|.
22
23 {\small BETTER} \cite{kris2014}:
24 The
25 |\frenchspacing| (|\nonfrenchspacing|)
26 command puts approximately
27 one (two)
28 spaces after sentences.
29 The default is |\nonfrenchspacing|.
30
31 {\small BEST} \cite{cms17-slashes-to-signify-alternatives}:
32 The
33 |\frenchspacing|/|\nonfrenchspacing|
34 command puts approximately
35 one/two
36 spaces after sentences.
37 The default is |\nonfrenchspacing|.
38
39 {
40   \frenchspacing
41   Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam
42   cursus. Morbi ut mi. Nullam enim leo, egestas id, condimentum at,
43   laoreet mattis, massa. Sed eleifend nonummy diam. Praesent mauris
44   ante, elementum et, bibendum at, posuere sit amet, nibh. Duis
45   tincidunt lectus quis dui viverra vestibulum. Suspendisse
46   vulputate aliquam dui. Nulla elementum dui ut augue. Aliquam
47   vehicula mi at mauris. Maecenas placerat, nisl at consequat
48   rhoncus, sem nunc gravida justo, quis eleifend arcu velit quis
49   lacus. Morbi magna magna, tincidunt a, mattis non, imperdiet
50   vitae, tellus. Sed odio est, auctor ac, sollicitudin in,
51   consequat vitae, orci. Fusce id felis. Vivamus sollicitudin metus
52   eget eros.\endgraf
53 }
54
55 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam
56 cursus. Morbi ut mi. Nullam enim leo, egestas id, condimentum at,
57 laoreet mattis, massa. Sed eleifend nonummy diam. Praesent mauris
58 ante, elementum et, bibendum at, posuere sit amet, nibh. Duis
59 tincidunt lectus quis dui viverra vestibulum. Suspendisse
60 vulputate aliquam dui. Nulla elementum dui ut augue. Aliquam
61 vehicula mi at mauris. Maecenas placerat, nisl at consequat
62 rhoncus, sem nunc gravida justo, quis eleifend arcu velit quis
63 lacus. Morbi magna magna, tincidunt a, mattis non, imperdiet
64 vitae, tellus. Sed odio est, auctor ac, sollicitudin in,
65 consequat vitae, orci. Fusce id felis. Vivamus sollicitudin metus
66 eget eros.

```

## U.5 Multiple Columns

Depending on what version of  $\text{\LaTeX}$  you're running the `multicols` package may or may not do what you want.

This is one columnThis is one column. This is one column. This is one column. This is one column. This is one column. This is one column. This is one column. This is one column. This is one column. This is one column.

This is two columns. This is two columns. | This is two columns. This is two columns.  
This is two columns. This is two columns. | This is two columns. This is two columns.  
This is two columns. This is two columns. | This is two columns. This is two columns.

This is three columns. | three columns. This is | three columns. This is  
This is three columns. This | three columns. This is | three columns. This is three  
is three columns. This is | three columns. This is | columns.

This is four | columns. This is four | columns. This is four | columns. This is four  
columns. This is four | columns. This is four | columns. This is four | columns.  
columns. This is four | columns. This is four | columns. This is four |

This is five | This is five | This is five | This is five | This is five  
columns. This is | columns. This is | columns. This is | columns. This is |  
five columns. | five columns. | five columns. | five columns. | five columns.

```
1 \section{Multiple Columns}
2
3 Depending on what version of \LaTeX you're running
4 the \verb+multicols+ package may or may not do what
5 you want.
6
7 % The multicols package must be loaded for this to work.
8 % To load the multicols package put
9 % \usepackage{multicols}
10 % between the "\documentclass" and "\begin{document}" commands.
11
12 % Put this amount of space between the columns.
13 % Let's use the default column separation to see what happens.
14 % \setlength{\columnsep}{0.5truein}
15
16 % Separate the columns with a vertical rule this wide.
17 % Make the column three times the default width.
18 \setlength{\columnseprule}{1.2pt}
19
20 This is one column\MyRepeat{This is one column. }{10}
21
22 \begin{multicols}{2}
23 \MyRepeat{This is two columns. }{12}
24 \end{multicols}
25
26 \begin{multicols}{3}
27 \MyRepeat{This is three columns. }{9}
28 \end{multicols}
29
30 \begin{multicols}{4}
31 \MyRepeat{This is four columns. }{10}
```

```

32 \end{multicols}
33
34 \begin{multicols}{5}
35 \MyRepeat{This is five columns. }{10}
36 \end{multicols}

```

## U.6 Words

**irregardless** is a nonstandard word that means regardless. Use *regardless* instead [88].

**out of date / out-of-date** means “outmoded, obsolete”. [89].

When it comes after the noun, the compound adjective usually doesn’t get a hyphen. So we say an easy-to-remember number, but the number is easy to remember. Same goes for up to date—if it’s before a noun it needs a hyphen. A document is up to date but it’s an up-to-date document [90]. Also see [89].

In the context of writing about out-of-date software you may want to use “deprecated” [59] instead.

**start-up / start-up company** means a fledgling business enterprise [91]. I would use the more modern *startup* and only use *company* if not clear from the context.

**peace out** means “goodbye” [92]

```

1
2
3 \section{Words}
4
5 \newenvironment{entry}
6 {%
7 \bigskip
8 % Start a \vbox here.
9 % Everything in a \vbox is guaranteed to be on the same page.
10 \vbox\bgroup
11 \noindent
12 }
13 {%
14 % End the \vbox here.
15 \egroup
16 }
17
18 \begin{entry}
19 {\bfseries irregardless}\quad
20 is a nonstandard word that means regardless.
21 Use \emph{regardless} instead
22 \cite{merriam-webster-irregardless}.
23 \end{entry}
24
25 \begin{entry}
26 {\bfseries out of date / out-of-date}\quad
27 means ‘‘outmoded, obsolete’’.
28 \cite{oed-out-of-date}.
29
30 When it comes after the noun,
31 the compound adjective usually doesn’t get a hyphen.
32 So we say an easy-to-remember number,

```



```

33 but the number is easy to remember.
34 Same goes for up to date---if it's before a noun it needs a hyphen.
35 A document is up to date but it's an up-to-date document
36 \cite{thewriter-to-hyphenate-or-not-to-hyphenate}.
37 Also see
38 \cite{oed-out-of-date}.
39
40 In the context of writing about out-of-date software you may want to
41 use ‘‘deprecated’’ \cite{merriam-webster-deprecated} instead.
42 \end{entry}
43
44 \begin{entry}
45   {\bfseries start-up / start-up company}\quad
46   means a fledgling business enterprise
47   \cite{wikipedia-startup-company}.
48   I would use the more modern \emph{startup}
49   and only use \emph{company} if not clear from the context.
50 \end{entry}
51
52 \begin{entry}
53   {\bfseries peace out}\quad
54   means
55   ‘‘goodbye’’
56   \cite{online-slang-dictionary-peace-out}
57 \end{entry}

```

## V. ASTRONOMY

```
1 \chapter{ASTRONOMY}
2 \ix{astronomy//Astronomy appendix}
3
4 \ix{astronomy}
5
```

## W. BIOLOGY

- 1 \chapter{BIOLOGY}
- 2
- 3 \ix{Biology appendix}

## X. CHEMISTRY

```
1 \chapter{CHEMISTRY}
2 \label{ch:chemistry}
3
4 \ix{chemistry}
5 \ix{Chemistry appendix}
6
```

### X.1 Chemical Diagrams

The chemplants package [93] extends the `TikZ` package to draw chemical process units.

```
1
2
3 \section{Chemical Diagrams}
4
5 The chemplants package
6 \cite{feffin2019}
7 extends the
8 \href{http://ctan.math.washington.edu/tex-archive/graphics/pgf/base/doc/pgfmanual.pdf}{\TikZLogo}
9 package
10 to draw chemical process units.
```

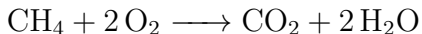
### X.2 Chemical Equations

The mhchem Bundle [94] contains mhchem v4.08 (chemical equations), hpstatement v1.02 (official hazard and precautionary statements), and rsphrase v3.11 (official risk and safety phrases).

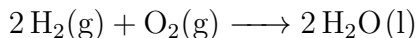
```
1
2
3 \section{Chemical Equations}
4
5 The mhchem Bundle
6 \cite{hensel2018}
7 contains mhchem v4.08 (chemical equations),
8 hpstatement v1.02 (official hazard and precautionary statements),
9 and rsphrase v3.11 (official risk and safety phrases).
```

Defined in thesis.tex:  $\text{NO}_3^-$ .

```
1
2 Defined in thesis.tex: \nitrate.
```



```
1
2 % See page 1 of
3 % https://www.thoughtco.com/what-is-a-chemical-equation-604026
4 \ce{CH4 + 2O2 -> CO2 + 2H2O}
```



```

1
2 % See page 1 of
3 % https://www.thoughtco.com/what-is-a-chemical-equation-604026
4 \ce{2H2(g) + O2(g) -> 2H2O(l)}

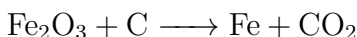
```

$\text{Ag}^+(\text{aq}) + \text{NO}_3^-(\text{aq}) + \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \longrightarrow \text{AgCl}(\text{s}) + \text{Na}^+(\text{aq}) + \text{NO}_3^-(\text{aq})$  is an ionic equation of the chemical reaction:  $\text{AgNO}_3(\text{aq}) + \text{NaCl}(\text{aq}) \longrightarrow \text{AgCl}(\text{s}) + \text{NaNO}_3(\text{aq})$

```

1
2 % See page 1 of
3 % https://www.thoughtco.com/definition-of-ionic-equation-605262
4 \ce{Ag+(aq) + NO3-(aq) + Na+(aq) + Cl-(aq) -> AgCl(s) + Na+(aq) + NO3-(aq)}
5 is an ionic equation of the chemical reaction:
6 \ce{AgNO3(aq) + NaCl(aq) -> AgCl(s) + NaNO3(aq)}

```

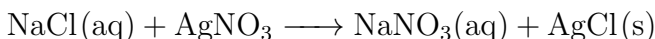


```

1
2 % See page 1 of
3 % https://www.thoughtco.com/definition-of-balanced-equation-and-examples-604380
4 \ce{Fe2O3 + C -> Fe + CO2}

```

For example, in the reaction between sodium chloride ( $\text{NaCl}$ ) and silver nitrate ( $\text{AgNO}_3$ ), the molecular reaction is:

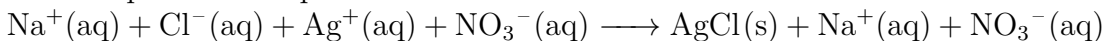


```

1
2 % From page 1 of
3 % https://www.thoughtco.com/definition-of-molecular-equation-605366
4
5 For example, in the reaction between sodium chloride
6 (\ce{NaCl})
7 and silver nitrate
8 (\ce{AgNO3}),
9 the molecular reaction is:
10
11 \ce{NaCl(aq) + AgNO3 -> NaNO3(aq) + AgCl(s)}

```

The complete ionic equation is:

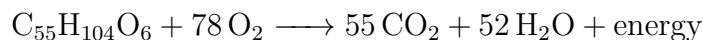


```

1
2 The complete ionic equation is:
3
4 \ce{Na+(aq) + Cl-(aq) + Ag+(aq) + NO3-(aq) -> AgCl(s) + Na+(aq) + NO3-(aq)}

```

Ruben [95, starting at 5:25] claims this equation



describes weight loss.

```

1
2 Ruben
3 \cite[starting at 5:25]{meerman2013}
4 claims this equation
5 \begin{center}
6 \ce{C55H104O6 + 78O2 -> 55CO2 + 52H2O + energy}\endgraf
7 \end{center}
8 describes weight loss.

```



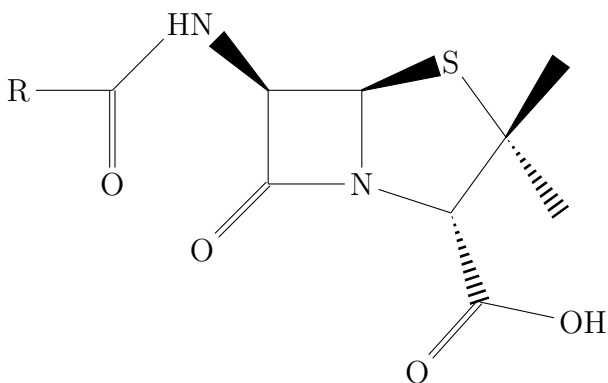
```

31      & \ce{7802}                % 3.
32      & \ce{->}                % 4.
33      & \ce{55C02}              % 5.
34      & \ce{+}                  % 6.
35      & \ce{52H20}              % 7.
36      & \ce{+}                  % 8.
37      & energy\\                % 9.
38      %
39      \Fs human fat&            % 1.
40      &                          % 2.
41      \Fs oxygen&              % 3.
42      &                          % 4.
43      \Fs carbon dioxide&      % 5.
44      &                          % 6.
45      \Fs water&                % 7.
46      &                          % 8.
47      \Fs body heat, moving, thinking, growing\\ % 9.
48      \end{tabular}
49      \end{center}

```

### X.3 Chemical Figures

Below is an example of how to use the chemfig package [96].  
Here is the chemical figure for Penicillin [96, pages 72–73]



```

1
2
3 \section{Chemical Figures}
4
5 Below is an example of how to use the chemfig package
6 \cite{tellechea2021}.
7
8 % Chicago Manual of Style Online, 17 edition, section 9.61 states
9 % that 72--73, not 72--3, should be used.
10 Here is the chemical figure
11 for Penicillin
12 \cite[pages-72--73]{tellechea2021}\\
13
14 \chemfig{
15   [:-90]HN(-[::-45](-[::-45]R)=[:+45]O)>[:+45]*4(- (=O)-N*5(- (<[::-60]O)
16   -[:+60]OH)-(<[:+0])(<[::-108])>-S>)--
17 }

```

## X.4 Chemical Schemes

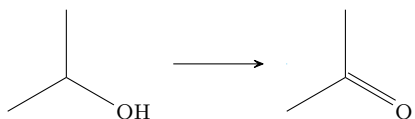
Below are some examples of how to do schemes.

**Scheme X.1.** This is the first scheme caption.

This is the first scheme.

```
1 \newpage
2 \section{Chemical Schemes}
3
4 Below are some examples of how to do schemes.
5
6 \begin{scheme}[ht]
7   \caption{This is the first scheme caption.}
8   \vspace*{6pt}
9   \begin{center}
10    This is the first scheme.
11   \end{center}
12 \end{scheme}
```

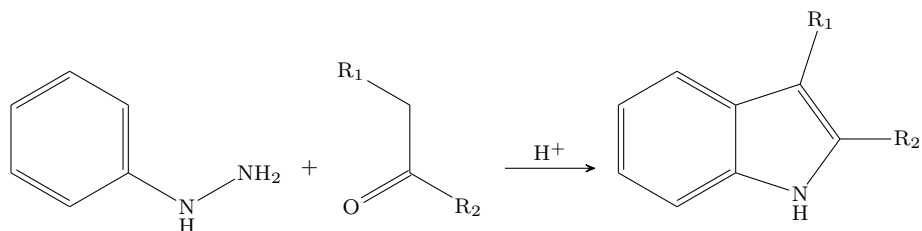
**Scheme X.2.** This is the second scheme caption.



```
1 \begin{scheme}[ht]
2   \caption{This is the second scheme caption.}
3   \vspace*{6pt}
4   \begin{center}
5     % Next line was added to make scheme a little smaller.
6     \scriptsize\setchemfig{bond offset=1pt,atom sep=3em,compound sep=6em}
7     \schemestart
8     \chemfig{-[:30](-[2])-[:30]OH}
9     \arrow
10    \chemfig{-[:30](-[2])=^[:30]O}
11    \schemestop
12  \end{center}
13 \end{scheme}
```



**Scheme X.3.** The Fischer indole synthesis [96, pages 74–75].

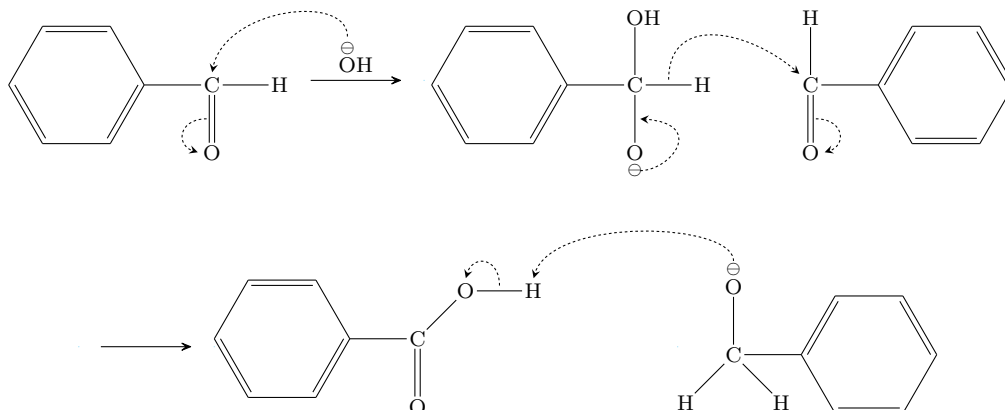


```

1 \newpage
2 \begin{scheme}[ht]
3   \caption[The Fischer indole synthesis]{%
4     The Fischer indole synthesis
5     \cite[pages-74--75]{tellechea2021}.%
6   }
7   \vspace*{6pt}
8   \begin{center}
9     % Next line was added to make scheme a little smaller.
10    \scriptsize\setchemfig{bond offset=1pt,atom sep=3em,compound sep=6em}
11    \schemestart
12    \chemfig{*6(=*6(-\chembelow{N}{H}-NH_2)=-=)}
13    \+
14    \chemfig{([:-150]O)(-[:-30]R_2)-[2]-[:150]R_1}
15    \arrow(.mid east--.mid west){->[\chemfig{H^+}]}
16    \chemfig{*6(=*5(-\chembelow{N}{H}-(-R_2)=(-R_1)-)-==)}
17    \schemestop
18  \end{center}
19 \end{scheme}

```

Scheme X.4. The Cannizzaro reaction [96, pages 77–78].



```

1 \newpage
2 \begin{scheme}[ht]
3   \caption[The Cannizzaro reaction.]{%
4     The Cannizzaro reaction
5     \cite[pages-77--78]{tellechea2021}.%
6   }
7   \vspace*{12pt}
8   \begin{center}
9     % Next line was added to make scheme a little smaller.
10    \scriptsize\setchemfig{bond offset=1pt,atom sep=3em,compound sep=6em}
11    \schemestart
12    \chemfig{[: -30]*6(=--(-@{atoc}C([6]=[@{db}]@{atoo1}O)-H)-==)}
13    \arrow[start.mid east--.mid west]{->[\chemfig{@{atoo2}\chemabove{0}{\scriptstyle\ominus}}H]}
14    \chemmove[-stealth,shorten >=2pt,dash pattern=on 1pt off 1pt,thin]{
15      \draw[shorten <=8pt](atoo2) ..controls +(up:10mm) and +(up:10mm)..(atoc);
16      \draw[shorten <=2pt](db) ..controls +(left:5mm) and +(west:5mm)..(atoo1);}
17    \chemfig{[: -30]*6(=--(-C([6]-[@{sb1}]@{atoo1}\chembelow{0}{\scriptstyle\ominus})
18      ([2]-OH)-[@{sb2}]H)-==)}
19    \hspace{1cm}
20    \chemfig{[: -30]*6((-@{atoc}C([6]=[@{db}]@{atoo2}O)-[2]H)-==--)}
21    \chemmove[-stealth,shorten <=2pt,shorten >=2pt,dash pattern=on 1pt off 1pt,thin]{
22      \draw([yshift=-4pt]atoo1.270) ..controls +(0:5mm) and +(right:10mm)..(sb1);
23      \draw(sb2) ..controls +(up:10mm) and +(north west:10mm)..(atoc);
24      \draw(db) ..controls +(right:5mm) and +(east:5mm)..(atoo2);}
25    \arrow{@start.base west--}{0}[-75,2]
26    {}
27    \arrow
28    \chemfig{[: -30]*6(=--(-C([1]-@{atoo2}O)-[@{sb}0]@{atoh}H)([6]=O)-==)}
29    \arrow{0}
30    \chemfig{[: -30]*6((-C(-[5]H)(-[7]H)-[2]@{atoo1}\chemabove{0}{\scriptstyle\ominus})-==--)}
31    \chemmove[-stealth,shorten >=2pt,dash pattern=on 1pt off 1pt,thin]{
32      \draw[shorten <=7pt](atoo1.90) ..controls +(90:8mm) and +(up:10mm)..(atoh);
33      \draw[shorten <=2pt](sb) ..controls +(up:5mm) and +(up:5mm)..(atoo2);}
34    \schemestop
35    \end{center}
36  \end{scheme}

```

## Y. COMPUTER SCIENCE

The cryptocode package [97] is used to typeset pseudocode, algorithms, and protocols.

```
1 \chapter{COMPUTER SCIENCE}
2 \ix{computer science//Computer Science appendix}
3
4 The cryptocode package
5 \cite{mittelbach2020}
6 \ix{cryptocode//pseudocode//algorithm//protocol}%
7 is used to typeset pseudocode,
8 algorithms,
9 and protocols.
```

### Y.1 Protocol examples

**Protocol Y.1.** This is the first protocol caption.

This is the first protocol.

**Protocol Y.2.** This is the second protocol caption.

<b>Alice</b>	<b>Bob</b>
$b \leftarrow \{0, 1\}$	
	$\xrightarrow{\text{send over } b}$
	do something

```
1
2
3 \section{Protocol examples}
4
5 \begin{protocol}[ht]
6   \caption{This is the first protocol caption.}
7   This is the first protocol.
8 \end{protocol}
9
10 \begin{protocol}[ht]
11   \caption{This is the second protocol caption.}
12   \pseudocodeblock
13   {
14     \textbf{Alice} \> \> \textbf{Bob} \\
15     b \sample \bin \> \> \\
16     \> \xrightarrow{\text{send over } b} \> \\
17     \> \> \text{do something}
18   }
19 \end{protocol}
```

## Z. ELECTRICAL ENGINEERING

```

1 \chapter{ELECTRICAL ENGINEERING}
2 \ix{electrical engineering//Electrical Engineering appendix}

```

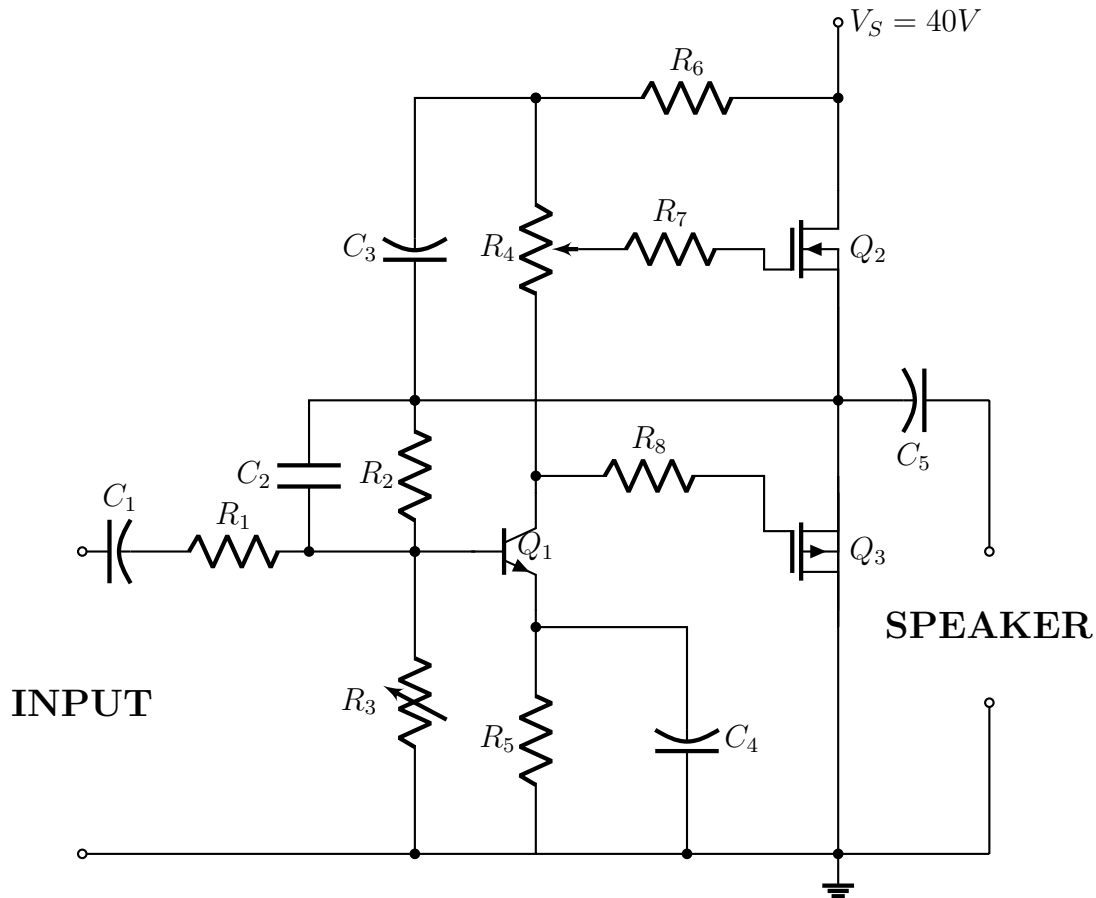
### Z.1 Amplifiers

```

1
2
3 \section{Amplifiers}

```

This 18 W MOSFET amplifier with npn transistor was done by Ramón Jaramillo [98]. This example make uses the CircuiTikZ [99] and siunitx packages.



```

1 This \qty{18}{\W} MOSFET amplifier
2 with npn transistor was done by Ram'on Jaramillo
3 \cite{jaramillo}.
4 \ix{Jaramillo, Ram'on}
5 This example make uses the \CircuiTikZLogo\index{\CircuiTikZLogo}
6 \cite{redaelli2021}
7 \ix{Redaelli, Massimo A.}%
8 and siunitx packages.
9
10 \begin{tikzpicture}[scale=2]
11 \draw[color=black, thick]
12 (0,0) to [short,o-] (6,0){} % Baseline for connection to ground
13 % Input and ground

```

```

14      (0,1) node[\large\textbf{INPUT}}
15      % Connection of passive components
16      (5,0) node[ground]{} node[circ](4.5,0){}
17      (0,2) to [cC, l=$C_1$, o-] (0.5,2)
18      to [R,l=$R_1$,] (1.5,2)
19      to node[short]{}(2.6,2)
20      (1.5,2) to [C, l=$C_2$, *-] (1.5,3) -| (5,3)
21      (2.2,2) to [R, l=$R_2$, *-] (2.2,3)
22      (2.2,3) to [cC, l=$C_3$, *-] (2.2,5) -| (3,5)
23      % Transistor Bipolar Q1
24      (3,0) to [R,l=$R_5$,*-] (3,1.5)
25      to [Tnpn,n=npn1] (3,2.5)
26      (npn1.E) node[right=3mm, above=5mm]{$Q_1$} % Labelling the NPN transistor
27      (4,0) to [cC, l=$C_4$, *-] (4, 1.5)--(3,1.5)
28      (2.2,0) to [vR, l=$R_3$, *-] (2.2,2)
29      (3,2.5) to node[short]{}(3,3)
30      (3,5) to [pR, n=pot1, l=$R_4$, *-] (3,3)
31      (3,5) to [R, l=$R_6$, *-] (5,5)
32      to [short,*-o] (5,5.5) node[right]{$V_S=40$ V$}
33      % Mosfet Transistors
34      (5,3) to [Tnigfetd,n=mos1] (5,5)
35      (mos1.B) node[anchor=west]{$Q_2$} % Labelling MOSFET Q2 Transistor
36      (pot1.wiper) to [R, l=$R_7$,] (4.5,4) -| (mos1.G)
37      (5,1.5) to [Tpigfetd,n=mos2] (5,2.5)
38      (5,0) to (mos2.S)
39      (3,2.5) to [R, l=$R_8$, *-] (4.5,2.5)
40      -| (mos2.G)
41      (mos2.B) node[anchor=west]{$Q_3$} % Labelling MOSFET Q3 Transistor
42      % Output
43      (6,3) to [cC, l=$C_5$,*-] (5,3)
44      (6,3) to [short,-o] (6,2){}
45      (mos1.S)--(mos2.D)
46      (6,0) to [short,-o] (6,1){} node[above=7mm]{\large\textbf{SPEAKER}}
47      ;
48      \end{tikzpicture}

```

## Z.2 Kalman Filter System Model

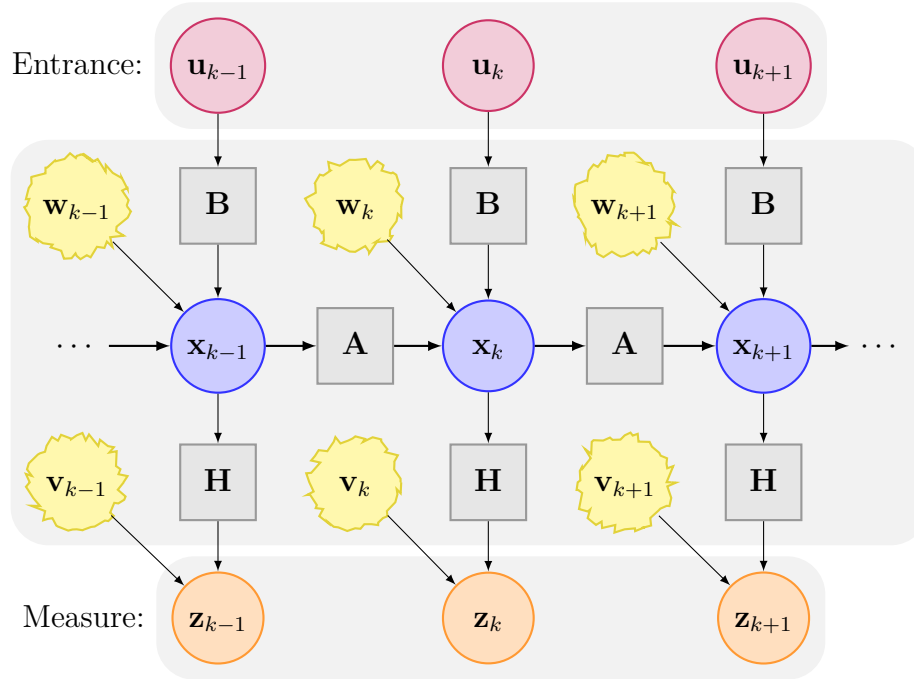
This Kalman filter system model was done by Burkart Lingner [100].

```

1
2
3      \section{Kalman Filter System Model}
4
5      This Kalman filter system model was done by Burkart Lingner
6      \cite{lingner2010}.
7      \ix{Lingner, Burkart}
8
9      % An example using TikZ/PGF 2.00
10     %
11     % Features: Decorations, Fit, Layers, Matrices, Styles
12     % Tags: Block diagrams, Diagrams
13     % Technical area: Electrical engineering
14
15     %%% \documentclass[a4paper,10pt]{article}
16     %%%
17     %%% \usepackage[english]{babel}
18     %%% \usepackage[T1]{fontenc}
19     %%% \usepackage[ansinew]{inputenc}
20     %%%
21     %%% \usepackage{lmodern}          % font definition

```

Figure Z.1. Kalman filter system model



```

22 %%%% \usepackage{amsmath}          % math fonts
23 %%%% \usepackage{amsthm}
24 %%%% \usepackage{amsfonts}
25 %%%%
26 %%%% \usepackage{tikz}
27 %%%%
28 %%%% %%%<
29 %%%% \usepackage{verbatim}
30 %%%% \usepackage[active,tightpage]{preview}
31 %%%% \PreviewEnvironment{tikzpicture}
32 %%%% \setlength\PreviewBorder{5pt}%
33 %%%% %%%>
34 %%%%
35 %%%% \begin{comment}
36 %%%% :Title: Kalman Filter System Model
37 %%%% :Slug: kalman-filter
38 %%%% :Author: Burkart Lingner
39 %%%%
40 %%%% This is the system model of the (linear) Kalman filter.
41 %%%%
42 %%%% \end{comment}
43 %%%%
44 %%%%
45
46 \begin{figure}[htbp]
47 \caption{Kalman filter system model}
48 \centering
49 % The state vector is represented by a blue circle.
50 % "minimum size" makes sure all circles have the same size
51 % independently of their contents.
52 \tikzstyle{state}=[circle,
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85

```

```

86             minimum size=1.2cm,
87             draw=yellow!85!black,
88             fill=yellow!40,
89             decorate,
90             decoration={random steps,
91                             segment length=2pt,
92                             amplitude=2pt}]
93
94 % Everything is drawn on underlying gray rectangles with
95 % rounded corners.
96 \tikzstyle{background}=[rectangle,
97                             fill=gray!10,
98                             inner sep=0.2cm,
99                             rounded corners=5mm]
100
101 \begin{tikzpicture}[>=latex,text height=1.5ex,text depth=0.25ex]
102     % "text height" and "text depth" are required to vertically
103     % align the labels with and without indices.
104
105     % The various elements are conveniently placed using a matrix:
106     \matrix[row sep=0.5cm,column sep=0.5cm] {
107         % First line: Control input
108         &
109         \node (u_{k-1}) [input] {$\mathbf{u}_{k-1}$}; &
110         &
111         \node (u_k) [input] {$\mathbf{u}_k$}; &
112         &
113         \node (u_{k+1}) [input] {$\mathbf{u}_{k+1}$}; &
114         \\
115         % Second line: System noise & input matrix
116         \node (w_{k-1}) [noise] {$\mathbf{w}_{k-1}$}; &
117         \node (B_{k-1}) [matrix] {$\mathbf{B}$}; &
118         \node (w_k) [noise] {$\mathbf{w}_k$}; &
119         \node (B_k) [matrix] {$\mathbf{B}$}; &
120         \node (w_{k+1}) [noise] {$\mathbf{w}_{k+1}$}; &
121         \node (B_{k+1}) [matrix] {$\mathbf{B}$}; &
122         \\
123         % Third line: State & state transition matrix
124         \node (A_{k-2}) {$\cdots$}; &
125         \node (x_{k-1}) [state] {$\mathbf{x}_{k-1}$}; &
126         \node (A_{k-1}) [matrix] {$\mathbf{A}$}; &
127         \node (x_k) [state] {$\mathbf{x}_k$}; &
128         \node (A_k) [matrix] {$\mathbf{A}$}; &
129         \node (x_{k+1}) [state] {$\mathbf{x}_{k+1}$}; &
130         \node (A_{k+1}) {$\cdots$}; & \\
131         % Fourth line: Measurement noise & measurement matrix
132         \node (v_{k-1}) [noise] {$\mathbf{v}_{k-1}$}; &
133         \node (H_{k-1}) [matrix] {$\mathbf{H}$}; &
134         \node (v_k) [noise] {$\mathbf{v}_k$}; &
135         \node (H_k) [matrix] {$\mathbf{H}$}; &
136         \node (v_{k+1}) [noise] {$\mathbf{v}_{k+1}$}; &
137         \node (H_{k+1}) [matrix] {$\mathbf{H}$}; &
138         \\
139         % Fifth line: Measurement
140         &
141         \node (z_{k-1}) [measurement] {$\mathbf{z}_{k-1}$}; &
142         &
143         \node (z_k) [measurement] {$\mathbf{z}_k$}; &
144         &
145         \node (z_{k+1}) [measurement] {$\mathbf{z}_{k+1}$}; &
146         \\
147     };
148
149     % The diagram elements are now connected through arrows:

```



```

150 \path[->]
151     (A_k-2) edge[thick] (x_k-1)           % The main path between the
152     (x_k-1) edge[thick] (A_k-1)         % states via the state
153     (A_k-1) edge[thick] (x_k)           % transition matrices is
154     (x_k) edge[thick] (A_k)             % accentuated.
155     (A_k) edge[thick] (x_k+1)           % x -> A -> x -> A -> ...
156     (x_k+1) edge[thick] (A_k+1)
157
158     (x_k-1) edge (H_k-1)                 % Output path x -> H -> z
159     (H_k-1) edge (z_k-1)
160     (x_k) edge (H_k)
161     (H_k) edge (z_k)
162     (x_k+1) edge (H_k+1)
163     (H_k+1) edge (z_k+1)
164
165     (v_k-1) edge (z_k-1)                 % Output noise v -> z
166     (v_k) edge (z_k)
167     (v_k+1) edge (z_k+1)
168
169     (w_k-1) edge (x_k-1)                 % System noise w -> x
170     (w_k) edge (x_k)
171     (w_k+1) edge (x_k+1)
172
173     (u_k-1) edge (B_k-1)                 % Input path u -> B -> x
174     (B_k-1) edge (x_k-1)
175     (u_k) edge (B_k)
176     (B_k) edge (x_k)
177     (u_k+1) edge (B_k+1)
178     (B_k+1) edge (x_k+1)
179     ;
180
181 % Now that the diagram has been drawn, background rectangles
182 % can be fitted to its elements. This requires the TikZ
183 % libraries "fit" and "background".
184 % Control input and measurement are labeled. These labels have
185 % not been translated to English as "Measurement" instead of
186 % "Messung" would not look good due to it being too long a word.
187 \begin{pgfonlayer}{background}
188     \node [background,
189           fit=(u_k-1) (u_k+1),
190           label=left:Entrance:] {};
191     \node [background,
192           fit=(w_k-1) (v_k-1) (A_k+1)] {};
193     \node [background,
194           fit=(z_k-1) (z_k+1),
195           label=left:Measure:] {};
196 \end{pgfonlayer}
197 \end{tikzpicture}
198
199 \end{figure}

```

## AA. LINGUISTICS

See WIKIBOOKS  $\LaTeX$ /Linguistics [101] or google for the information you need.

The doulossil font [102] is a TrueType font. Version 0.1 on September 21, 2020 claimed “it has characters that are not in other TeX IPA fonts”.

```
1 \chapter{LINGUISTICS}
2 \ix{linguistics//Linguistics appendix}
3
4 See WIKIBOOKS  $\LaTeX$ /Linguistics \cite{wikibooks-latex-linguistics}
5 or google for the information you need.
6
7 The doulossil font
8 \cite{tambe2020}
9 is a TrueType font.
10 Version 0.1 on September 21, 2020 claimed
11 ‘‘it has characters that are not in other TeX IPA fonts’’.
```

### AA.1 Demonstrate the example and examples environments

The example and examples environment are defined in the covington [103] package.

Demonstrate the example environment:

**Example AA.1.1.** This is an example. This is an example.

Demonstrate the examples environment:

A.1)

First example.

A.2)

Second example.

```
1
2
3 \section{Demonstrate the example and examples environments}
4
5 The example and examples environment
6 are defined
7 in the covington
8 \cite{covington2021}
9 package.
10
11 Demonstrate the example environment:
12 \begin{example}
13   This is an example.
14   This is an example.
15 \end{example}
16
17 Demonstrate the examples environment:
18 \begin{examples}
19   \item First example.
20   \item Second example.
21 \end{examples}
```

## AB. MATHEMATICS

PurdueThesis loads the AMSmath package [104] to do mathematics.

```
1 \chapter{MATHEMATICS}
2 \ix{mathematics//Mathematics appendix}
3
4 \PurdueThesisLogo\ loads the \AMSMathLogo\ package
5 \cite{amslatex3project2019}
6 to do mathematics.
```

There are two types of mathematics in L<sup>A</sup>T<sub>E</sub>X. Text math is interspersed with text. For example, this is text math:  $a = b + c$ . Display math is not interspersed with text. For example, this is display math:

$$a = b + c \tag{AB.1}$$

```
1 There are two types of mathematics in \LaTeXLogo.
2 Text math is interspersed with text.
3 For example,
4 this is text math: \(\a = b + c\).
5 Display math is not interspersed with text.
6 For example,
7 this is display math:
8 \begin{equation}
9   a = b + c
10 \end{equation}
```

### AB.1 Text Math

Use  $\($  to start text math and  $\)$  to end text math. Some people use  $\$$  to start and end text math—I don't recommend that because L<sup>A</sup>T<sub>E</sub>X can give better error messages if you use  $\($  and  $\)$  [105].

```
1
2
3 \section{Text Math}
4
5 Use \(\|
6 to start text math
7 and \)|
8 to end text math.
9 Some people use |$|
10 to start and end text math---I don't
11 recommend that because \LaTeXLogo\ can give better error messages
12 if you use \(\|
13 and \)|
14 \cite{meckes2010}.
```

### AB.2 Display Math

Use one of the below environments to start and end display math. Some people use  $\$$  to start and end displayed math but L<sup>A</sup>T<sub>E</sub>X doesn't officially support  $\$$  [106].

```

1
2
3 \section{Display Math}
4
5 Use one of the below environments to start and end display math.
6 Some people use  $7 to start and end displayed math
8 but \LaTeX\ doesn't officially support  $9 \cite{alpert2010}.
10
11$$ 
```

## AB.2.1 Displayed Equations

Do not use  $to start or end displayed math like  $uses [107].$$

The  $package provides a number of additional displayed equation structures beyond the ones provided in basic  $. The augmented set includes [108]:$$

Environment	Used for
<code>equation</code>	used for single equations
<code>multline</code>	split single equations over multiple lines
<code>gather</code>	collect but do not align multiple equations
<code>align</code>	align multiple equations
<code>alignat</code>	aligns multiple equations at multiple places
<code>flalign</code>	aligns multiple equations at multiple places on full length lines
<code>split</code>	split a single equation over multiple lines

All but `split` can be followed by `*` to not number equations.

```

1
2
3 \subsection{Displayed Equations}
4
5 Do not use
6  $7 to start or end displayed math like \TeX\ uses
8 \cite{gratzer2016}.
9 \todoerror{add page number to reference}
10
11 The \AMSMathLogo\ package provides a number
12 of additional displayed equation structures
13 beyond the ones provided in basic \LaTeX.
14 The augmented set includes
15 \cite{amslatex3project2019b}:
16
17 \hbox to\hsize{%
18   \hss
19   \begin{tabular}{@{}l@{}}
20     \toprule
21     \bfseries Environment& \bfseries Used for\\
22     \midrule
23     \tt equation& used for single equations\\
24     \tt multline& split single equations over multiple lines\\
25     \tt gather& collect but do not align multiple equations\\
26     \tt align& align multiple equations\\
27     \tt alignat& aligns multiple equations at multiple places\\
28     \tt flalign& aligns multiple equations at multiple places on full length lines\\$ 
```

```

29     \tt split& split a single equation over multiple lines\\
30     \bottomrule
31     \end{tabular}%
32     \hss
33 }
34
35 All but
36 |split|
37 can be followed by
38 |*|
39 to not number equations.

```

## equation environment

The `equation` environment is used for single equations.

$$E = mc^2 \tag{AB.2}$$

```

1
2 \subsubsection{\texttt{equation} environment}
3
4 The
5 |equation|
6 environment is used for single equations.
7
8 \begin{equation}
9     E = mc^2
10 \end{equation}

```

The `equation*` environment does single, unnumbered equations.

$$a = b_0c + \frac{1}{2}de^2 + \frac{1}{2}fg^2 + h_1 + h_2 + \cdots + h_n \quad \text{for } c \neq d \text{ and } g < \infty$$

```

1
2 The
3 |equation*|
4 environment does single, unnumbered equations.
5
6 \begin{equation*}
7     a = b_0c + \frac{1}{2}de^2 + {\textstyle \frac{1}{2}} fg^2
8         + h_1 + h_2 + \cdots + h_n
9     \quad \text{for } (c \neq d) \text{ and } (g < \infty)
10 \end{equation*}

```

Greene [109] wrote For [#PiDay](#), one of the coolest formulae for today's honoree:

$$\frac{1}{\pi} = \frac{\sqrt{8}}{9801} \sum_{n=0}^{\infty} \frac{(4n!)(1103 + 26390n)}{(n!)^4 396^{4n}}$$

```

1
2 \textcite{greene-2021-03-14}
3 wrote
4 % \begin{quotation}
5     For
6     \href{https://twitter.com/hashtag/PiDay?src=hashtag_click\#PiDay}{\#PiDay},
7     one of the coolest formulae for today's honoree:

```

```

8 \[
9 \frac 1\pi
10 =
11 \frac {\sqrt{8} {9801}
12 \sum_{n=0}^{\infty}
13 \frac {(4n!) (1103+26390n)} {(n!)^4 396^{4n}}
14 \]
15 % \end{quotation}

```

The formula for Bekenstein-Hawking entropy:

$$S_{\text{BH}} = \frac{A}{4L_P^2} = \frac{c^3 A}{4G\hbar}$$

```

1
2 The formula for Bekenstein-Hawking entropy:
3
4 \begin{equation*}
5 S_{\text{BH}}
6 =
7 \frac A {4L_P^2}
8 = \frac {c^3A} {4G\hbar}
9 \end{equation*}

```

Type in the math and let L<sup>A</sup>T<sub>E</sub>X worry about the spacing. You only need to do fine tuning by hand if it looks bad.

Another `equation*` environment, note the spacing before the large close parenthesis:

$$\frac{a}{b} = ab^{-1} = \left(\sqrt{\frac{a}{b}}\right)^2 = \left(\sqrt{\frac{a}{b}}\right)^2 = \left(\sqrt{\frac{a}{b}}\right)^2 = \left(\sqrt{\frac{a}{b}}\right)^2 = \left(\sqrt{\frac{a}{b}}\right)^2 = \left(\sqrt{\frac{a}{b}}\right)^2$$

```

1
2 Type in the math and let \LaTeX\ worry about the spacing.
3 You only need to do fine tuning by hand if it looks bad.
4
5 Another
6 |equation*|
7 environment,
8 note the spacing before the large close parenthesis:
9
10 \begin{equation*}
11 \frac ab
12 = ab^{-1}
13 % Pareds are the wrong size.
14 = (\sqrt{\frac ab})^2
15 % Pareds are the right size but closing paren is too close to radical.
16 = \left( \sqrt{\frac ab} \right)^2
17 % Pareds are right size but a negative thin space puts closing paren on top of radical.
18 = \left( \sqrt{\frac ab} \!\right)^2
19 % Pareds are right size but a thin space puts closing paren too close to radical.
20 = \left( \sqrt{\frac ab} \,\right)^2
21 % Pareds are right size but a medium space puts closing paren too close to radical.
22 = \left( \sqrt{\frac ab} \:\right)^2
23 % Pareds are right size and I think a thick space looks the best.
24 = \left( \sqrt{\frac ab} \;\right)^2
25 \end{equation*}

```

$$(\cos x)^2 + (\sin x)^2 = \cos^2 x + \sin^2 x = 1$$

```

1
2 \begin{equation*}
3 (\cos x)^2 + (\sin x)^2 = \cos^2 x + \sin^2 x = 1
4 \end{equation*}

```

$$x \bmod 2 = \begin{cases} 0 & \text{if } x \text{ is even} \\ 1 & \text{if } x \text{ is odd} \end{cases} \quad (\text{AB.3})$$

```

1
2 \begin{equation}
3 x \bmod 2 =
4 \begin{cases}
5 0 & \text{\text{if } (x) \text{ is even}} \\
6 1 & \text{\text{if } (x) \text{ is odd}}
7 \end{cases}
8 \end{equation}

```

The first six derivatives of distance are velocity, acceleration, jerk, snap, crackle, and pop [110].

$$\text{distance derivatives} = \left\{ \begin{array}{l} x = \text{distance} = vt \\ v = \text{velocity} = \frac{dx}{dt} \\ a = \text{acceleration} = \frac{dv}{dt} = \frac{d^2x}{dt^2} \\ j = \text{jerk} = \frac{da}{dt} = \frac{d^2v}{dt^2} = \frac{d^3x}{dt^3} \\ s = \text{snap} = \frac{dj}{dt} = \frac{d^2a}{dt^2} = \frac{d^3v}{dt^3} = \frac{d^4x}{dt^4} \\ c = \text{crackle} = \frac{ds}{dt} = \frac{d^2j}{dt^2} = \frac{d^3a}{dt^3} = \frac{d^4v}{dt^4} = \frac{d^5x}{dt^5} \\ p = \text{pop} = \frac{dc}{dt} = \frac{d^2s}{dt^2} = \frac{d^3j}{dt^3} = \frac{d^4a}{dt^4} = \frac{d^5v}{dt^5} = \frac{d^6x}{dt^6} \end{array} \right. \quad (\text{AB.4})$$

```

1
2 The first six derivatives of distance are velocity, acceleration, jerk, snap, crackle,
3 and pop
4 \cite{reid2013}.
5 \ix{distance//velocity//acceleration//jerk//snap//crackle//pop}
6
7 \begin{equation}
8 % Every array element should be in \displaystyle (a big font).
9 \AtBeginEnvironment{array}{\everymath{\displaystyle}}
10 % Set space between columns to zero, use {} = ... to add a little space before the = "by hand".
11 \arraycolsep = 0pt
12 \text{distance derivatives} = \left\{ \left\{ \begin{array}{l}
13 \begin{array}{l}
14 % I'm formatting the first 4 lines different from the last 3 so this will fit on one page.
15 x& {}=\text{distance}& {}=vt\[\2pt]
16 v& {}=\text{velocity}& {}=\frac{\di x}{\di t}\[\9pt]

```

```

17   a& {}=\text{acceleration}& {}=\frac{\di v}{\di t}& {}=\frac{\di^2x}{\di t^2}\[9pt]
18   \mit j& {}=\text{jerk}& {}=\frac{\di a}{\di t}& {}=\frac{\di^3x}{\di t^3}& {}=\frac{\di^2v}{\di t^2}&
19   {}=\frac{\di^3x}{\di t^3}\[9pt]
20   s
21   & {}=\text{snap}
22   & {}=\frac{\di \mit j}{\di t}
23   & {}=\frac{\di^2a}{\di t^2}
24   & {}=\frac{\di^3v}{\di t^3}
25   & {}=\frac{\di^4x}{\di t^4}\[9pt]
26   c
27   & {}=\text{crackle}
28   & {}=\frac{\di s}{\di t}
29   & {}=\frac{\di^2\mit j}{\di t^2}
30   & {}=\frac{\di^3a}{\di t^3}
31   & {}=\frac{\di^4v}{\di t^4}
32   & {}=\frac{\di^5x}{\di t^5}\[9pt]
33   p
34   & {}=\text{pop}
35   & {}=\frac{\di c}{\di t}
36   & {}=\frac{\di^2s}{\di t^2}
37   & {}=\frac{\di^3\mit j}{\di t^3}
38   & {}=\frac{\di^4a}{\di t^4}
39   & {}=\frac{\di^5v}{\di t^5}
40   & {}=\frac{\di^6x}{\di t^6}
41   \end{array}
42   \right.
43   \end{equation}

```

## multline environment

The `multline` environment is used to split single equations over multiple lines.

$$\begin{aligned}
 S = a + b + c + d + e + f + g + h + i + j \\
 + k + l + m + n + o + p \\
 + q + r + s + t + u + v + w + x + y + z \quad (\text{AB.5})
 \end{aligned}$$

```

1
2   \subsubsection{\texttt{multline} environment}
3
4   The
5   |multline|
6   environment is used
7   to split single equations over multiple lines.
8
9   \begin{multline}
10  S = a + b + c + d + e + f + g + h + i + j\
11  + k + l + m + n + o + p\
12  + q + r + s + t + u + v + w + x + y + z
13  \end{multline}

```



$$\begin{aligned}
S &= a + b + c + d + e \\
&\quad + f + g + h + i + j \\
&\quad + k + l + m + n + o \\
&\quad + p + q + r + s + t \\
&\quad + u + v + w + x + y \\
&\quad + z \tag{AB.6}
\end{aligned}$$

```

1
2 \begin{multline}
3   S = a + b + c + d + e \\
4   + f + g + h + i + j \\
5   + k + l + m + n + o \\
6   + p + q + r + s + t \\
7   + u + v + w + x + y \\
8   + z \\
9 \end{multline}

```

$$\begin{aligned}
S &= a + b + c + d + e \\
&\quad + f + g + h + i + j \\
&\quad\quad + k + l + m + n + o \\
&\quad\quad\quad + p + q + r + s + t \\
&\quad\quad\quad\quad + u + v + w + x + y \\
&\quad\quad\quad\quad + z \tag{AB.7}
\end{aligned}$$

```

1
2 % Calculate width of space before equation plus equation number.
3 % (All digits are the same width.)
4 \newdimen{\tdimen}
5 \settowidth{\tdimen}{\kern\multlinetaggap (L.5)}
6 \begin{multline}
7   S = a + b + c + d + e \\
8   \makebox[\textwidth]{\hfill \{+ f + g + h + i + j\}\hfill\hfill\hfill\hfill\kern\tdimen} \\
9   \makebox[\textwidth]{\hfill\hfill\{+ k + l + m + n + o\}\hfill\hfill\hfill\kern\tdimen} \\
10  \makebox[\textwidth]{\hfill\hfill\hfill\{+ p + q + r + s + t\}\hfill\hfill\kern\tdimen} \\
11  \makebox[\textwidth]{\hfill\hfill\hfill\hfill\{+ u + v + w + x + y\}\hfill\kern\tdimen} \\
12  + z \\
13 \end{multline}

```

### gather environment

The `gather` environment collects but does not align multiple equations.

$$a = b + c + d + e + f + g + h + i + j + k + l \tag{AB.8}$$

$$m = n + o + p + q + r + s + t + u + v + w + x + y + z \tag{AB.9}$$

```

1
2 \subsubsection{\texttt{gather} environment}
3
4 The
5 |gather|
6 environment collects but does not align multiple equations.
7
8 \begin{gather}
9   a = b + c + d + e + f + g + h + i + j + k + l \\
10  m = n + o + p + q + r + s + t + u + v + w + x + y + z
11 \end{gather}

```

$$\begin{aligned}
 a &= b + c + d + e + f + g + h + i + j + k + l \\
 m &= n + o + p + q + r + s + t + u + v + w + x + y + z
 \end{aligned}
 \tag{AB.10}$$

```

1
2 \begin{gather}
3   a = b + c + d + e + f + g + h + i + j + k + l \notag \\
4   m = n + o + p + q + r + s + t + u + v + w + x + y + z
5 \end{gather}

```

$$\begin{aligned}
 \alpha &= \beta + \gamma + \delta + \eta \\
 \theta &= \iota + \kappa + \lambda + \mu + \nu + \rho + \tau
 \end{aligned}$$

```

1
2 \begin{gather*}
3   \alpha = \beta + \gamma + \delta + \eta \\
4   \theta = \iota + \kappa + \lambda + \mu + \nu + \rho + \tau
5 \end{gather*}

```

$$x_{\min} + x_{\max} \leq \sum_{i=1}^n x_i \tag{AB.11}$$

$$x_{\min} + x_{\max} = \sum_{i=1}^n x_i - \sum_{i=2}^{n-1} x_i \quad \text{if } x \text{ is sorted} \tag{AB.12}$$

$$x_{\min} \leq \left( \sum_{i=1}^n x_i \right) / n \tag{AB.13}$$

```

1
2 \begin{gather}
3   x_{\text{\texttt{min}}} + x_{\text{\texttt{max}}} \le \sum_{i=1}^n x_i \\
4   x_{\text{\texttt{min}}} + x_{\text{\texttt{max}}} \\
5   = \sum_{i=1}^n x_i - \sum_{i=2}^{n-1} x_i \quad \text{\texttt{if } (x) \text{ is sorted}} \\
6   x_{\text{\texttt{min}}} \le \left( \sum_{i=1}^n x_i \right) / n
7 \end{gather}

```

## align environment

The `align` environment aligns multiple equations.

$$a = b + c + d \tag{AB.14}$$

$$e = f + g + h + i + j \tag{AB.15}$$

```
1
2 \subsubsection{\texttt{align} environment}
3
4 The
5 |align|
6 environment aligns multiple equations.
7
8 \begin{align}
9   a &= b + c + d \\
10  e &= f + g + h + i + j
11 \end{align}
```

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \tag{AB.16}$$

```
1
2 \begin{align}
3   x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}\notag \\
4   % Put a thin space before the b^2 to improve the appearance.
5   x = \frac{-b \pm \sqrt{\,b^2-4ac}}{2a}
6 \end{align}
```

Quadratic formula proof [111]:

$$ax^2 + bx + c = 0 \tag{AB.17}$$

$$ax^2 + bx = -c$$

$$x^2 + \frac{b}{a}x = -\frac{c}{a}$$

$$x^2 + \frac{b}{a}x + \frac{b^2}{4a^2} = \frac{b^2}{4a^2} - \frac{c}{a}$$

$$\left(x + \frac{b}{2a}\right)^2 = \frac{b^2}{4a^2} - \frac{c}{a}$$

$$\left(x + \frac{b}{2a}\right)^2 = \frac{b^2}{4a^2} - \frac{4ac}{4a^2}$$

$$\left(x + \frac{b}{2a}\right)^2 = \frac{b^2 - 4ac}{4a^2}$$

$$\sqrt{\left(x + \frac{b}{2a}\right)^2} = \sqrt{\left(\frac{b^2 - 4ac}{4a^2}\right)}$$

$$x + \frac{b}{2a} = \pm \frac{\sqrt{b^2 - 4ac}}{\sqrt{4a^2}}$$

$$x + \frac{b}{2a} = \pm \frac{\sqrt{b^2 - 4ac}}{2a}$$

$$x = -\frac{b}{2a} \pm \frac{\sqrt{b^2 - 4ac}}{2a}$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \tag{AB.18}$$

```

1
2 Quadratic formula proof
3 \cite{khan2018}:
4 \ix{quadratic formula}
5
6 % The align environment requires the amsmath package.
7 % Use \addtolength{\jot}{6pt} to increase the space between rows in an amsmath multi-line math formula.
8 % That's not done here so everything will fit on one page.
9 \begin{align}
10 ax^2 + bx + c &= 0 \\
11 ax^2 + bx &= -c \notag \\
12 % The "\," adds a thinspace of horizontal space.
13 x^2 + \frac{b}{a}x &= -\frac{c}{a} \notag \\
14 x^2 + \frac{b}{a}x + \frac{b^2}{4a^2} &= \frac{b^2}{4a^2} - \frac{c}{a} \notag \\
15 \left(x + \frac{b}{2a}\right)^2 &= \frac{b^2}{4a^2} - \frac{c}{a} \notag \\
16 \left(x + \frac{b}{2a}\right)^2 &= \frac{b^2 - 4ac}{4a^2} \notag \\
17 \sqrt{\left(x + \frac{b}{2a}\right)^2} &= \sqrt{\frac{b^2 - 4ac}{4a^2}} \notag \\
18 &= \sqrt{\frac{b^2 - 4ac}{4a^2}} \notag \\
19 x + \frac{b}{2a} &= \pm \frac{\sqrt{b^2 - 4ac}}{\sqrt{4a^2}} \notag \\
20 x + \frac{b}{2a} &= \pm \frac{\sqrt{b^2 - 4ac}}{2a} \notag \\
21 x &= -\frac{b}{2a} \pm \frac{\sqrt{b^2 - 4ac}}{2a} \notag \\
22 x &= \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \\
23
24 \end{align}

```



38 Do whatever works best for you.  
 39

Quadratic formula proof [111]:

$ax^2 + bx + c = 0$	subtract $c$	(AB.23)
$ax^2 + bx = -c$	divide by $a$	
$x^2 + \frac{b}{a}x = -\frac{c}{a}$	add $\frac{b^2}{4a^2}$	
$x^2 + \frac{b}{a}x + \frac{b^2}{4a^2} = \frac{b^2}{4a^2} - \frac{c}{a}$	factor left hand side	
$\left(x + \frac{b}{2a}\right)^2 = \frac{b^2}{4a^2} - \frac{c}{a}$	multiply right-most term by $\frac{4a}{4a}$	
$\left(x + \frac{b}{2a}\right)^2 = \frac{b^2}{4a^2} - \frac{4ac}{4a^2}$	use common denominator	
$\left(x + \frac{b}{2a}\right)^2 = \frac{b^2 - 4ac}{4a^2}$	take square root of each side	
$\sqrt{\left(x + \frac{b}{2a}\right)^2} = \sqrt{\left(\frac{b^2 - 4ac}{4a^2}\right)}$	compute square root of each side	
$x + \frac{b}{2a} = \pm \frac{\sqrt{b^2 - 4ac}}{\sqrt{4a^2}}$	simplify right hand denominator	
$x + \frac{b}{2a} = \pm \frac{\sqrt{b^2 - 4ac}}{2a}$	subtract $\frac{b}{2a}$ from each side	
$x = -\frac{b}{2a} \pm \frac{\sqrt{b^2 - 4ac}}{2a}$	use common denominator	
$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$		(AB.24)

```

1
2 Quadratic formula proof
3 \cite{khan2018}:
4
5 % Make changes to \jot be local to the group that starts on the next line.
6 {
7   % Increase distance between lines by 6pt.
8   \addtolength{\jot}{6pt}
9   \begin{alignat}{2}
10    ax^2 + bx + c
  
```

```

11     &= 0
12     &
13     &\text{subtract \((c)\)}\\
14 ax^2 + bx
15     &= -c
16     &
17     &\text{divide by \((a)\)}\notag\\
18 % The "\", adds a thinspace of horizontal space.
19 x^2 + \frac{ba}{a},x
20     &= -\frac{ca}{a}
21     &
22     &\text{add \(\displaystyle\frac{b^2}{4a^2}\)}\notag\\
23 x^2+\frac{ba}{a},x+\frac{b^2}{4a^2}
24     &= \frac{b^2}{4a^2}-\frac{ca}{a}
25     &
26     &\text{factor left hand side}\notag\\
27 \left(x+\frac{b}{2a}\right)^2
28     &= \frac{b^2}{4a^2}-\frac{ca}{a}
29     &
30     &\text{multiply right-most term by \(\displaystyle\frac{4a}{4a}\)}\notag\\
31 \left(x + \frac{b}{2a}\right)^2
32     &= \frac{b^2}{4a^2}-\frac{4ac}{4a^2}
33     &
34     &\text{use common denominator}\notag\\
35 \left(x + \frac{b}{2a}\right)^2
36     &= \frac{b^2-4ac}{4a^2}
37     &
38     &\text{take square root of each side}\notag\\
39 \sqrt{\left(x + \frac{b}{2a}\right)^2}
40     &= \sqrt{\left(\frac{b^2-4ac}{4a^2}\right)}
41     &
42     &\text{compute square root of each side}\notag\\
43 x + \frac{b}{2a}
44     &= \pm \frac{\sqrt{b^2-4ac}}{\sqrt{4a^2}}
45     &
46     &\text{simplify right hand denominator}\notag\\
47 x + \frac{b}{2a}
48     &= \pm \frac{\sqrt{b^2-4ac}}{2a}
49     &
50     &\text{subtract \(\displaystyle\frac{b}{2a}\)} from each side}\notag\\
51 x
52     &= -\frac{b}{2a} \pm \frac{\sqrt{b^2-4ac}}{2a}
53     &\quad
54     &\text{use common denominator}\notag\\
55 x
56     &= \frac{-b \pm \sqrt{b^2-4ac}}{2a}
57 \end{alignat}
58 }

```

## flalign environment

The `flalign` environment aligns multiple equations at multiple places on full length lines.

$$a = b$$

$$c = d$$

$$g = h$$

$$m = n$$

$$u = v \text{ (AB.25)}$$

$$w = x$$

$$y = z \text{ (AB.26)}$$

```

1
2 \index{\verb+\begin{flalign}+}
3 \todoindex{Verb+Begin-0curly-flalign-Ccurly+}
4 \ix{falign environment}
5 \subsubsection{\texttt{flalign} environment}
6
7 The
8 |flalign|
9 environment aligns multiple equations at multiple places
10 on full length lines.
11
12 \begin{flalign}
13   a &= b& & & u &= v\\
14   c &= d& m &= n& w &= x\notag\\
15   g &= h& & & y &= z
16 \end{flalign}

```

## split environment

The split environment ???.

```

1
2 \index{\verb+\begin{split}+}
3 \todoindex{Verb+Begin-0curly-split-Ccurly+}
4 \ix{split environment}
5 \subsubsection{\texttt{split} environment}
6
7 The
8 |split|
9 environment ???
10 \index{\verb+\begin{split}+}
11 \todoindex{Verb+Begin-0curly-split-Ccurly+}
12 \ix{split environment}
13
14

```



### AB.3 Use the Following in Text or Display Math

The following constructs can be used in text or display math.

```
1
2
3 \newpage
4 \section{Use the Following in Text or Display Math}
5
6 The following constructs can be used in text or display math.
```

#### AB.3.1 Breaking Lines

This information is based on information from ISO 80000-2 [112, page 2]:

If an expression or equation must be split into two or more lines, place the line breaks immediately before one of the symbols =, +, -, ×, /, ±, ∓, etc.

Examples:

The alternating sum of the first 20 prime numbers is  $2 - 3 + 5 - 7 + 11 - 13 + 17 - 19 + 23 - 29 + 31 - 37 + 41 - 43 + 47 - 53 + 59 - 61 + 67 - 71$ .

$$\begin{aligned} s &= 2 - 3 + 5 - 7 + 11 - 13 + 17 - 19 + 23 - 29 \\ &\quad + 31 - 37 + 41 - 43 + 47 - 53 + 59 - 61 + 67 - 71 \end{aligned}$$

```
1
2 \subsection{Breaking Lines}
3
4 This information is based on information from ISO 80000-2
5 \cite[page 2]{iso80000-2}:
6 \begin{quote}
7   If an expression or equation must be split into two or more lines,
8   place the line breaks immediately before one of the symbols
9   \ (=),
10  \ (+),
11  \ (-),
12  \ (\times),
13  \ (/),
14  \ (\pm),
15  \ (\mp),
16  etc.
17 \end{quote}
18
19 Examples:
20
21 The alternating sum of the first 20 prime numbers is
22 \ (2 - 3 + 5 - 7 + 11 - 13 + 17 - 19\ + 23 - 29 + 31 - 37 + 41 - 43 + 47 - 53 + 59 - 61 + 67 - 71\ ).
23 \begin{align}
24   s = {} & \& 2 - 3 + 5 - 7 + 11 - 13 + 17 - 19 + 23 - 29\ \nonumber\ \
25           & \& + 31 - 37 + 41 - 43 + 47 - 53 + 59 - 61 + 67 - 71\ \nonumber
26 \end{align}
27
```

#### AB.3.2 Constants, etc., should be in an upright font

This information is based on information in ISO 80000-2 [112, page 1]:

- The constants  $e$ ,  $i$ ,  $j$ , and  $\pi$  should be typeset in an upright font as  $e$ ,  $i$ ,  $j$  and  $\pi$ .  
Example:  $e^{i\pi} + 1 = 0$ .
- The ordinary derivative operator  $d$  should be typeset in an upright font as ‘ $d$ ’.  
Example:  $\int 2x dx = x^2 + C$ .
- The partial derivative operator  $\partial$  should be typeset in an upright font as  $\partial$ . Example:  

$$\frac{\partial f}{\partial x} = f_x = \lim_{h \rightarrow 0} \frac{f(x+h, y) - f(x, y)}{h} = \lim_{h \rightarrow 0} \frac{f(x+h, y) - f(x, y)}{h}.$$

```

1
2 \subsection{Constants, etc., should be in an upright font}
3
4 This information is based on information
5 in ISO 80000-2
6 \cite[page 1]{iso80000-2}:
7 \begin{itemize}
8   \item
9     The constants  $e$ ,  $i$ ,  $j$ , and  $\pi$ 
10    should be typeset in an upright font as  $e$ ,  $i$ ,  $j$  and  $\pi$ .
11    Example:  $e^{i\pi} + 1 = 0$ .
12  \item
13    The ordinary derivative operator  $d$ 
14    should be typeset in an upright font as ‘ $d$ ’.
15    Example:  $\int 2x dx = x^2 + C$ .
16  \item
17    The partial derivative operator  $\partial$ 
18    should be typeset in an upright font as  $\partial$ .
19    Example:
20    \(\
21      \displaystyle
22      \frac{\partial f}{\partial x}
23      =
24      f_x
25      =
26      \lim_{h \rightarrow 0}
27      \frac{f(x+h, y) - f(x, y)}{h}
28      =
29      \lim_{h \rightarrow 0}
30      \frac{f(x+h, y) - f(x, y)}{h}
31    \).
32 \end{itemize}

```

The `thesis.tex` file sets up the first capability above with

```
% Follow ISO 80000-2:2019
%   o   put e, i, j, and pi in upright font automatically
%   o   use, for example, "\di x" to get "\,mathrm{d}\!/x"
\usepackage{pa-mismatch}
% Put e, i, j, and pi in upright font automatically.
% Comment the corresponding line to not put the symbol in an upright font.
\enumber
\inumber
\jnumber
\pinumber
% With the four lines above not commented out, to typeset math italic e,
% i, j, and pi use
%   \mathit e
%   \mathit i
%   \mathit j
%   \itpi

1  \newpage
2  The |thesis.tex| file sets up the first capability above with
3  \begin{verbatim}
4  % Follow ISO 80000-2:2019
5  %   o   put e, i, j, and pi in upright font automatically
6  %   o   use, for example, "\di x" to get "\,mathrm{d}\!/x"
7  \usepackage{pa-mismatch}
8  % Put e, i, j, and pi in upright font automatically.
9  % Comment the corresponding line to not put the symbol in an upright font.
10 \enumber
11 \inumber
12 \jnumber
13 \pinumber
14 % With the four lines above not commented out, to typeset math italic e,
15 % i, j, and pi use
16 %   \mathit e
17 %   \mathit i
18 %   \mathit j
19 %   \itpi
20 \end{verbatim}
```

### AB.3.3 English Words

English words in math should be in a roman font like this:

Let the maximum value of  $a$  be  $a_{\max}$ .

$a_{\max} \geq a_{\min}$  should always be true.

The temperature in the attic is  $t_{\text{attic}}$ .

```
1  \subsection{English Words}
2
3  English words in math should be in a roman font like this:\\
4  Let the maximum value of \(\a\) be \(\a_{\text{max}}\)\.\\
5  \(\a_{\text{max}} \geq a_{\text{min}}\) should always be true.\\
6  The temperature in the attic is \(\t_{\text{attic}}\).
```

### AB.3.4 Functions

Standard functions should be in a roman font. Like this:  $\cos \theta$ . Here is a list of standard function commands:

<code>\arccos</code>	<code>\csc</code>	<code>\ker</code>	<code>\min</code>
<code>\arcsin</code>	<code>\deg</code>	<code>\lg</code>	<code>\Pr</code>
<code>\arctan</code>	<code>\det</code>	<code>\lim</code>	<code>\sec</code>
<code>\arg</code>	<code>\dim</code>	<code>\liminf</code>	<code>\sin</code>
<code>\cos</code>	<code>\exp</code>	<code>\limsup</code>	<code>\sinh</code>
<code>\cosh</code>	<code>\gcd</code>	<code>\ln</code>	<code>\sup</code>
<code>\cot</code>	<code>\hom</code>	<code>\log</code>	<code>\tan</code>
<code>\coth</code>	<code>\inf</code>	<code>\max</code>	<code>\tanh</code>

```

1
2 \subsection{Functions}
3
4 Standard functions should be in a roman font.
5 Like this:  $\cos \theta$ .
6 Here is a list of standard function commands:\\
7
8 % The "@{\hspace*{\parindent}}" indents the table
9 % the same amount as a paragraph.
10 \begin{tabular}{@{\hspace*{\parindent}}llll@{}}
11 \verb+\arccos+& \verb+\csc+& \verb+\ker+& \verb+\min+\\
12 \verb+\arcsin+& \verb+\deg+& \verb+\lg+& \verb+\Pr+\\
13 \verb+\arctan+& \verb+\det+& \verb+\lim+& \verb+\sec+\\
14 \verb+\arg+& \verb+\dim+& \verb+\liminf+& \verb+\sin+\\
15 \verb+\cos+& \verb+\exp+& \verb+\limsup+& \verb+\sinh+\\
16 \verb+\cosh+& \verb+\gcd+& \verb+\ln+& \verb+\sup+\\
17 \verb+\cot+& \verb+\hom+& \verb+\log+& \verb+\tan+\\
18 \verb+\coth+& \verb+\inf+& \verb+\max+& \verb+\tanh+\\
19 \end{tabular}
20 \ix
21 {%
22 arccos//arcsin//arctan//arg//cos//cosh//cot//coth%
23 //csc//deg//det//dim//exp//gcd//hom//inf%
24 //ker//lg//lim//liminf//limsup//ln//log//max%
25 //min//Pr//sec//sin//sinh//sup//tan//tanh%
26 }
27 \index{\verb+\arccos+} \index{\verb+\arcsin+} \index{\verb+\arctan+} \index{\verb+\arg+}
28 \index{\verb+\cos+} \index{\verb+\cosh+} \index{\verb+\cot+} \index{\verb+\coth+}
29 \index{\verb+\csc+} \index{\verb+\deg+} \index{\verb+\det+} \index{\verb+\dim+}
30 \index{\verb+\exp+} \index{\verb+\gcd+} \index{\verb+\hom+} \index{\verb+\inf+}
31 \index{\verb+\ker+} \index{\verb+\lg+} \index{\verb+\lim+} \index{\verb+\liminf+}
32 \index{\verb+\limsup+} \index{\verb+\ln+} \index{\verb+\log+} \index{\verb+\max+}
33 \index{\verb+\min+} \index{\verb+\Pr+} \index{\verb+\sec+} \index{\verb+\sin+}
34 \index{\verb+\sinh+} \index{\verb+\sup+} \index{\verb+\tan+} \index{\verb+\tanh+}

```

### AB.3.5 Matrices

From ISO 80000-2 [112, page 18]:

Matrices are usually written with boldface italic capital letters and their elements with italic lower case letters, but other typefaces may be used.

Example: Let  $M$  be a  $3 \times 3$  matrix:

$$M = \begin{pmatrix} m_{1,1} & m_{1,2} & m_{1,3} \\ m_{2,1} & m_{2,2} & m_{2,3} \\ m_{3,1} & m_{3,2} & m_{3,3} \end{pmatrix} = \begin{pmatrix} a & b & c \\ d & e & f \\ g & h & i \end{pmatrix}$$

```

1
2 \subsection{Matrices}
3
4 From ISO 80000-2
5 \cite[page 18]{iso80000-2}:
6 \begin{quotation}
7   Matrices are usually written with boldface italic capital letters
8   and their elements with italic lower case letters,
9   but other typefaces may be used.
10  \todoerror{Double check this quote.}
11 \end{quotation}
12
13 Example:
14 Let  $\mathbf{M}$  be a  $(3 \times 3)$  matrix:
15 \begin{equation*}
16   \mathbf{M}
17   =
18   \left(
19     \begin{array}{ccc}
20       m_{1,1} & m_{1,2} & m_{1,3} \\
21       m_{2,1} & m_{2,2} & m_{2,3} \\
22       m_{3,1} & m_{3,2} & m_{3,3}
23     \end{array}
24   \right)
25   =
26   \left(
27     % If your thesis.tex is set up to assume, for example, 'e' is a constant
28     % and typeset in an upright font, use '\mit e' to typeset 'e' in a math
29     % italic font.
30     \begin{array}{ccc}
31       a & b & c \\
32       d & \mit e & f \\
33       g & h & \mit i
34     \end{array}
35   \right)
36 \end{equation*}

```

### AB.3.6 Sets

Use  $\mathbb{N}$  for the natural numbers.

Use  $\mathbb{R}$  for the real numbers.

Use  $\mathbb{Z}$  for the integers.

The Cartesian product of  $\mathbf{A}$  and  $\mathbf{B}$  is  $\mathbf{A} \times \mathbf{B} = \{(a, b) \mid a \in \mathbf{A} \text{ and } b \in \mathbf{B}\}$ .

The intersection of  $\mathbf{A}$  and  $\mathbf{B}$  is  $\mathbf{A} \cap \mathbf{B} = \{x \mid x \in \mathbf{A} \text{ and } x \in \mathbf{B}\}$ .

The union of  $\mathbf{A}$  and  $\mathbf{B}$  is  $\mathbf{A} \cup \mathbf{B} = \{x \mid x \in \mathbf{A} \text{ and } x \in \mathbf{B}\}$ .

```

1
2 \subsection{Sets}
3
4 % Make \newcommand local to { ... }.
5 {

```

```

6 % \St is short for my set.
7 \newcommand{\Se}[1]{\ensuremath{\mathbf{#1}}}
8 % \St is short for suchthat.
9 \newcommand{\St}{\mid}
10 \noindent
11 Use \(\mathbb{N}\) for the natural numbers.
12 \index{natural numbers}\
13 Use \(\mathbb{R}\) for the real numbers.
14 \index{real numbers}\
15 Use \(\mathbb{Z}\) for the integers.
16 \index{integers}\
17 The Cartesian product\index{\verb+\times+}\index{Cartesian product}
18 of \Se A and \Se B is
19 \(\Se A \times \Se B = \{(a,b) \St a \in \Se A \text{ and } b \in \Se B\}\).\
20 The intersection\index{\verb+\cap+}\index{intersection}
21 of \Se A and \Se B is
22 \(\Se A \cap \Se B = \{x \St x \in \Se A \text{ and } x \in \Se B\}\).\
23 The union\index{\verb+\cup+}\index{union}
24 of \Se A and \Se B is
25 \(\Se A \cup \Se B = \{x \St x \in \Se A \text{ and } x \in \Se B\}\).
26 }

```

## AB.4 Theorem-like environments

The `ntheorem` package is used instead of `amsthm` so the counter for a theorem-like construct can be overridden by the user. See [113, pages 4–5] and below for how to do this.

```

1
2
3 \section{Theorem-like environments}
4
5 The |ntheorem| package\index{ntheorem package}
6 is used instead of |amsthm|\index{amsthm package}
7 so the counter
8 for a theorem-like construct
9 can be overridden by the user.
10 See
11 \cite[pages 4--5]{may2011}
12 and below
13 for how to do this.

```

By default all theorem-like constructs:

acknowledgment	assertion	assumption	axiom	case	claim
conclusion	condition	conjecture	corollary	criterion	definition
example	exercise	hypothesis	lemma	notation	note
observation	problem	proof	property	proposition	question
remark	summary	theorem			

use the same counter.

```

1
2 By default all theorem-like constructs:\[6pt]
3 \begin{tabular}{@{\hspace*{2\parindent}}l11111l@{}}
4 acknowledgment& assertion& assumption& axiom& case& claim\\
5 conclusion& condition& conjecture& corollary& criterion& definition\\
6 example& exercise& hypothesis& lemma& notation& note\\
7 observation& problem& proof& property& proposition& question\\

```

```

8 remark&          summary&    theorem\\
9 \end{tabular}
10 \mbox{}\\[6pt]
11 use the same counter.

```

From PurdueThesis.cls:

```

\usepackage[amsthm]{ntheorem}
% From example 31 of https://math.mit.edu/~poonen/papers/writing.pdf
%   Use a single numbering system for all theorems, lemmas, etc.,
%   instead of having both a Theorem 1.1 and a Lemma 1.1 in the
%   same paper. This makes statements easier to find[...]
% For example,
%   \newtheorem{lemma}[theorem]{Lemma}
% makes lemma use the theorem counter.
\theoremstyle{plain}
\newtheorem{theorem}{Theorem}[section]
\newtheorem{lemma}[theorem]{Lemma}
[28 more lines]

```

To make, for example, lemma have its own counter put

```
\renewtheorem{lemma}{Lemma}[section]
```

in your thesis.tex file right after the `\begin{document}` statement.

```

1
2 From PurdueThesis.cls:
3 \begin{verbatim}
4   \usepackage[amsthm]{ntheorem}
5   % From example 31 of https://math.mit.edu/~poonen/papers/writing.pdf
6   %   Use a single numbering system for all theorems, lemmas, etc.,
7   %   instead of having both a Theorem 1.1 and a Lemma 1.1 in the
8   %   same paper. This makes statements easier to find[...]
9   % For example,
10  %   \newtheorem{lemma}[theorem]{Lemma}
11  % makes lemma use the theorem counter.
12  \theoremstyle{plain}
13  \newtheorem{theorem}{Theorem}[section]
14  \newtheorem{lemma}[theorem]{Lemma}
15  [28 more lines]
16 \end{verbatim}
17 To make,
18 for example,
19 lemma have its own counter put
20 \begin{verbatim}
21   \renewtheorem{lemma}{Lemma}[section]
22 \end{verbatim}
23 in your thesis.tex file right after the |\begin{document}| statement.

```

*Acknowledgment AB.4.1.* This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{acknowledgment}
3   \MyRepeat{This is a sentence. }{5}
4 \end{acknowledgment}
5 \index{\verb+\begin{acknowledgment}+}
6 \index{acknowledgment environment}

```

**Assertion AB.4.2.** *This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.*

```

1
2 \begin{assertion}
3   \MyRepeat{This is a sentence. }{5}
4 \end{assertion}
5 \index{\verb+\begin{assertion}+}
6 \index{assertion environment}

```

**Assumption AB.4.3.** This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{assumption}
3   \MyRepeat{This is a sentence. }{5}
4 \end{assumption}
5 \index{\verb+\begin{assumption}+}
6 \index{assumption environment}

```

**Axiom AB.4.4.** This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{axiom}
3   \MyRepeat{This is a sentence. }{5}
4 \end{axiom}
5 \index{\verb+\begin{axiom}+}
6 \index{axiom environment}

```

*Claim AB.4.5.* This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{claim}
3   \MyRepeat{This is a sentence. }{5}
4 \end{claim}
5 \index{\verb+\begin{claim}+}
6 \index{claim}

```

*Conclusion AB.4.6.* This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.



```

1
2 \begin{conclusion}
3   \MyRepeat{This is a sentence. }{5}
4 \end{conclusion}
5 \index{\verb+\begin{conclusion}+}
6 \index{conclusion environment}

```

**Condition AB.4.7.** This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{condition}
3   \MyRepeat{This is a sentence. }{5}
4 \end{condition}
5 \index{\verb+\begin{condition}+}
6 \index{condition environment}

```

**Conjecture AB.4.8.** *This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.*

```

1
2 \begin{conjecture}
3   \MyRepeat{This is a sentence. }{5}
4 \end{conjecture}
5 \index{\verb+\begin{conjecture}+}
6 \index{conjecture environment}

```

**Corollary AB.4.9.** *This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.*

```

1
2 \begin{corollary}
3   \MyRepeat{This is a sentence. }{5}
4 \end{corollary}
5 \index{\verb+\begin{corollary}+}
6 \index{corollary environment}

```

**Criterion AB.4.10.** *This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.*

```

1
2 \begin{criterion}
3   \MyRepeat{This is a sentence. }{5}
4 \end{criterion}
5 \index{\verb+\begin{criterion}+}
6 \index{criterion environment}

```

**Definition AB.4.11.** This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{definition}
3   \MyRepeat{This is a sentence. }{5}
4 \end{definition}
5 \index{\verb+\begin{definition}+}
6 \index{definition environment}

```

**Example AB.4.12.** This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{example}
3   \MyRepeat{This is a sentence. }{5}
4 \end{example}
5 \index{\verb+\begin{example}+}
6 \index{example environment}

```

**Exercise AB.4.13.** This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{exercise}
3   \MyRepeat{This is a sentence. }{5}
4 \end{exercise}
5 \index{\verb+\begin{exercise}+}
6 \index{exercise environment}

```

**Hypothesis AB.4.14.** This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{hypothesis}
3   \MyRepeat{This is a sentence. }{5}
4 \end{hypothesis}
5 \index{\verb+\begin{hypothesis}+}
6 \index{hypothesis environment}

```

**Lemma AB.4.15.** *This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.*

```

1
2 \begin{lemma}
3   \MyRepeat{This is a sentence. }{5}
4 \end{lemma}
5 \index{\verb+\begin{lemma}+}
6 \index{lemma environment}

```

*Notation AB.4.16.* This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{notation}
3   \MyRepeat{This is a sentence. }{5}
4 \end{notation}
5 \index{\verb+\begin{notation}+}
6 \index{notation environment}

```

*Note AB.4.17.* This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{note}
3   \MyRepeat{This is a sentence. }{5}
4 \end{note}
5 \index{\verb+\begin{note}+}
6 \index{note environment}

```

**Problem AB.4.18.** This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{problem}
3   \MyRepeat{This is a sentence. }{5}
4 \end{problem}
5 \index{\verb+\begin{problem}+}
6 \index{problem environment}

```

*Proof.* This is an example proof. This is an example proof. This is an example proof. This is an example proof. This is an example proof.

```

1
2 \begin{proof}
3   \MyRepeat{This is an example proof. }{5}
4 \end{proof}
5 \index{\verb+\begin{proof}+}
6 \index{proof environment}

```

**Property AB.4.19.** This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{property}
3   \MyRepeat{This is a sentence. }{5}
4 \end{property}
5 \index{\verb+\begin{property}+}
6 \index{property environment}

```

**Proposition AB.4.20.** *This is an example proposition. This is an example proposition. This is an example proposition. This is an example proposition. This is an example proposition.*

```

1
2 \begin{proposition}
3   \MyRepeat{This is an example proposition. }{5}
4 \end{proposition}
5 \index{\verb+\begin{proposition}+}
6 \index{proposition environment}

```

**Question AB.4.21.** This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{question}
3   \MyRepeat{This is a sentence. }{5}
4 \end{question}
5 \index{\verb+\begin{question}+}
6 \index{question environment}

```

*Remark AB.4.22.* This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{remark}
3   \MyRepeat{This is a sentence. }{5}
4 \end{remark}
5 \index{\verb+\begin{remark}+}
6 \index{remark environment}

```

*Summary AB.4.23.* This is a sentence. This is a sentence. This is a sentence. This is a sentence. This is a sentence.

```

1
2 \begin{summary}
3   \MyRepeat{This is a sentence. }{5}
4 \end{summary}
5 \index{\verb+\begin{summary}+}
6 \index{summary environment}

```

**Theorem AB.4.24.** *This is an example theorem. This is an example theorem. This is an example theorem. This is an example theorem. This is an example theorem.*

```

1
2 \begin{theorem}
3   \MyRepeat{This is an example theorem. }{5}
4 \end{theorem}
5 \index{\verb+\begin{theorem}+}
6 \index{theorem environment}

```

## AB.5 Examples

### AB.5.1 Bayes' Theorem

Bayes' Theorem [114] is

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)} \quad (\text{AB.27})$$

```
1
2
3 \section{Examples}
4
5 \subsection{Bayes' Theorem}
6 \ix{Bayes' Theorem}
7 \ix{Bayes, Thomas}
8
9 Bayes' Theorem
10 \cite{bayes}
11 is
12 {
13   \UndefShortVerb{\|}
14   \begin{equation}
15     \text{P}(\text{A}|\text{B})
16     % The "\", puts a thin horizontal space there, 1/6 of an "em".
17     % An "em" is roughly the width of a lowercase "m".
18     = \frac{\text{P}(\text{B}|\text{A})\text{P}(\text{A})}{\text{P}(\text{B})}
19   \end{equation}
20 }
```

### AB.5.2 Euler's identity

Euler's identity [115] is

$$e^{i\pi} + 1 = 0. \quad (\text{AB.28})$$

```
1
2 \subsection{Euler's identity}
3 \ix{Euler's identity}
4 \ix{Euler, Leonhard}
5
6 Euler's identity
7 \cite{eulers-identity}
8 is
9 \begin{equation}
10   e^{i\pi} + 1 = 0.
11 \end{equation}
```

### AB.5.3 Fourier transform

ISO 80000-2 [112, page 25] recommends using  $\mathcal{F}$  nfor the Fourier transform. The Fourier transform of  $f$  is  $(\mathcal{F}f)(\omega) = \mathcal{F}(\omega) = \int_{-\infty}^{\infty} e^{i\omega t} f(t) dt$ .

```
1
2 \subsection{Fourier transform}
```

```

3 \ix{Fourier Transform}
4
5 ISO 80000-2
6 \cite[page 25]{iso80000-2}
7 recommends using
8 \(\Fourier\)
9 nfor the Fourier transform.
10 The Fourier transform of \(\f\) is
11 \(\
12 \displaystyle
13 (\Fourier f)(\omega)
14 = \Fourier (\omega)
15 = \int_{-\infty}^{\infty} e^{i\omega t} f(t) \, dt
16 \).

```

### AB.5.4 Laplace transform

ISO 80000-2 [112, page 25] recommends using  $\mathcal{L}$  for the Laplace transform. The Laplace transform of  $s$  is  $(\mathcal{L}f)(s) = \mathcal{L}(s) = \int_0^{\infty} e^{-st} f(t) dt$ .

```

1
2 \subsection{Laplace transform}
3 \ix{Laplace Transform}
4
5 ISO 80000-2
6 \cite[page 25]{iso80000-2}
7 recommends using
8 \(\Laplace\)
9 for the Laplace transform.
10 The Laplace transform of \(\s\) is
11 \(\
12 \displaystyle
13 (\Laplace f)(s)
14 = \Laplace(s)
15 = \int_0^{\infty} e^{-st} f(t) \, dt
16 \).

```

### AB.5.5 Nicomachus's theorem

Nicomachus's theorem [116] states that the sum of the first  $n$  cubes is the square of the  $n$ th triangular number. That is,

$$1^3 + 2^3 + 3^3 + \cdots + n^3 = (1 + 2 + 3 + \cdots + n)^2. \quad (\text{AB.29})$$

The same equation may be written more compactly using the mathematical notation for summation:

$$\sum_{k=1}^n k^3 = \left( \sum_{k=1}^n k \right)^2.$$

Also see the diagram on that web page.

```

1
2 \subsection{Nicomachus's theorem}
3 \ix{Nicomachus's theorem}

```

```

4 \ix{Nicomachus of Gerasa}
5 Nicomachus's theorem
6 \cite{wikipedia-nicomachus}
7 states that
8 the sum of the first-\(n\) cubes is the square of the-\(n\)th triangular number.
9 That is,
10 \begin{equation}
11 1^3 + 2^3 + 3^3 + \cdots + n^3 = (1 + 2 + 3 + \cdots + n)^2.
12 \end{equation}
13 The same equation may be written more compactly using the mathematical notation for summation:
14 \begin{equation*}
15 \sum_{k=1}^n k^3 = \left(\sum_{k=1}^n k\right)^2.
16 \end{equation*}
17 Also see the diagram on that web page.

```

## AB.5.6 Prime Number Theorem

Li [117] suggested using a functional equation from the Prime Number Theorem proof as an example:

$$\int_1^x \sum_{p \leq u} \left\lfloor \frac{\log u}{\log p} \right\rfloor \log p \, du = \frac{1}{2\pi i} \int_{c-i\infty}^{c+i\infty} \frac{x^{s+1}}{s(s+1)} \left( -\frac{\zeta'(s)}{\zeta(s)} \right) ds \quad (\text{AB.30})$$

```

1
2 \subsection{Prime Number Theorem}
3 \ix{Prime Number Theorem}
4
5 \textcite{li2013}
6 \ix{Li, Henry}
7 suggested using a functional equation
8 from the Prime Number Theorem proof
9 as an example:
10 \begin{equation}
11 \int_1^x
12 \sum_{p \leq u}
13 \left\lfloor \frac{\log u}{\log p} \right\rfloor
14 \log p
15 \, di u
16 =
17 \frac{1}{2\pi i}
18 \int_{c-i\infty}^{c+i\infty}
19 \frac{x^{s+1}}{s(s+1)}
20 \left( -\frac{\zeta'(s)}{\zeta(s)} \right)
21 \, di s
22 \end{equation}

```

## AB.5.7 Quantum Mechanics

Greene [118] wrote

Quantum Mechanics in a nutshell: A particle goes from here to there by sampling every possible trajectory from here to there.

$$\langle x_f, t_f | x_i, t_i \rangle = \sum_{p \in \text{paths}} e^{iS(p)\hbar}$$

```

1
2 \subsection{Quantum Mechanics}
3 \ix{Quantum Mechanics}
4
5 \textcite{greene-2021-04-04}
6 wrote
7 \ix{Greene, Brian Randolph}
8 \begin{quotation}
9   Quantum Mechanics in a nutshell:
10  A particle goes from here to there
11  by sampling every possible trajectory from here to there.
12
13  \[
14   \langle x_f, t_f \mid x_i, t_i \rangle
15   =
16   \sum_{\text{paths}} e^{iS} \hbar^{-1}
17  \]
18 \end{quotation}

```

### AB.5.8 Question in String Theory / Mass of States / Number Operator

yourlazyphysicist [119] wrote “I have the following definition of the space-time coordinates”:

$$\text{closed string: } \begin{cases} X_R^\mu = \frac{1}{2}x^\mu + \frac{1}{4\pi T}(\tau - \sigma)p^\mu + \frac{i}{\sqrt{4\pi T}} \sum_{n \neq 0} \frac{1}{n} \alpha_n^\mu e^{-in(\tau - \sigma)}, \\ X_L^\mu = \frac{1}{2}x^\mu + \frac{1}{4\pi T}(\tau + \sigma)p^\mu + \frac{i}{\sqrt{4\pi T}} \sum_{n \neq 0} \frac{1}{n} \tilde{\alpha}_n^\mu e^{-in(\tau + \sigma)}. \end{cases} \quad (\text{AB.31})$$

$$\text{open string: } \begin{cases} X_N^\mu = x^\mu + \frac{1}{\pi T}p^\mu \tau + \frac{i}{\sqrt{\pi T}} \sum_{n \neq 0} \frac{1}{n} \alpha_n^\mu e^{-in\tau} \cos(n\sigma), \\ X_D^\mu = x^\mu + \frac{i}{\sqrt{\pi T}} \sum_{n \neq 0} \frac{1}{n} \alpha_n^\mu e^{-in\tau} \sin(n\sigma). \end{cases} \quad (\text{AB.32})$$

```

1
2 \subsection{Question in String Theory / Mass of States / Number Operator}
3
4 \textcite{yourlazyphysicist2017}
5 wrote
6 ‘‘I have the following definition of the space-time coordinates’’:
7 {
8   % The following five definitions are local to inside the { ... }.
9   \newcommand{\fpt}{4\pi T}
10  \newcommand{\oh}{\frac{1}{2}}
11  \newcommand{\snnz}{\sum_{n \neq 0}}
12  \newcommand{\tms}{\tau - \sigma}
13  \newcommand{\tps}{\tau + \sigma}
14  \begin{align}
15    \text{closed string: } & \\
16    \begin{cases}
17      \displaystyle
18      X^\mu_R
19      = \oh x^\mu
20      + \frac{1}{\fpt} (\tms) p^\mu
21      + \frac{i}{\sqrt{\fpt}} \snnz \frac{1}{n} \alpha_n^\mu e^{-in(\tms)}, \backslash

```



```

22     \displaystyle
23     X^{\mu_L}
24     = \oh x^{\mu}
25     + \frac{1}{\sqrt{\pi}} (\frac{1}{\sqrt{\pi}})^{\mu}
26     + \frac{i}{\sqrt{\pi}} \sum_{n=1}^{\infty} \frac{\alpha_n}{n} e^{-in(\frac{1}{\sqrt{\pi}})}.
27 \end{cases}][6pt]
28 \text{open string: }&
29 \begin{cases}
30     \displaystyle
31     X^{\mu_N}
32     = x^{\mu}
33     + \frac{1}{\sqrt{\pi}} p^{\mu} \tau
34     + \frac{i}{\sqrt{\pi}} \sum_{n=1}^{\infty} \frac{\alpha_n}{n} e^{-in\tau} \cos(n\sigma), \\
35     \displaystyle
36     X^{\mu_D}
37     = x^{\mu}
38     + \frac{i}{\sqrt{\pi}} \sum_{n=1}^{\infty} \frac{\alpha_n}{n} e^{-in\tau} \sin(n\sigma).
39 \end{cases}
40 \end{align}
41 }

```

### AB.5.9 Willans' Formula

An *Exact Formula for the Primes: Willans' Formula* [120] is a good video about Willans' Formula by Eric Rowland:

$$\text{nth prime} = 1 + \sum_{i=1}^{2^n} \left[ \left( \frac{n}{\sum_{j=1}^i \left[ \left( \cos \pi \frac{(j-1)! + 1}{j} \right)^2 \right]} \right)^{1/n} \right] \tag{AB.33}$$

```

1
2 \subsection{Willans' Formula}
3
4 \citetitle{rowland2022}
5 \cite{rowland2022}
6 \ix{Willans, C. P.}
7 \ix{Rowland, Eric Samuel}
8 is a good video about Willans' Formula by Eric Rowland:
9
10 \begin{equation}
11 % Typeset i and j in a math italic font for this equation only.
12 \MathIt{i}
13 \MathIt{j}
14 \text{\(n\)th prime}
15 =
16 1
17 +
18 \sum_{i = 1}^{2^n}
19 \left\lfloor \left( \frac{n}{\sum_{j=1}^i \left[ \left( \cos \pi \frac{(j-1)! + 1}{j} \right)^2 \right]} \right)^{1/n} \right\rfloor
20 \left(
21 \frac{n}{
22 {
23 \displaystyle % so \sum limits are above and below and to make denominator bigger
24 \sum_{j=1}^i
25 \left\lfloor \left( \cos \pi \frac{(j-1)! + 1}{j} \right)^2 \right\rfloor
26 }

```

```

27         \left(
28         % use \, for a tiny bit of horizontal space
29         \cos \pi \, \frac {(j-1)! + 1} j
30         \right)^2
31     \right\rceil
32 }
33 \right)^{1/n}
34 \right\rceil
35 \end{equation}

```

## AC. MUSIC

To get the following printed music score I did the following steps.

- Get the “Example of LilyPond input file” from the Wikipedia LilyPond page [121] and put it in a `fib.ly` file.
- Run `lilypond fib.ly` to get the following `fib.pdf` file:

### Excerpt from *fibonacci*

Patrick McCarty

Slow and steady ( $\text{♩} = 60$ )

57

Music engraving by LilyPond 2.22.0—[www.lilypond.org](http://www.lilypond.org)

```
1 \chapter{MUSIC}
2 \ix{music//Music appendix}
3
4 To get the following printed music score I did the following steps.
5 \begin{itemize}
6   \item
7     Get the ‘‘Example of LilyPond input file’’
8     from the Wikipedia LilyPond page
9     \cite{wikipedia-lilypond}
10    and put it in a
11    |fib.ly|
12    file.
13   \item
14     Run \Shell{lilypond fib.ly} to get the following
15     |fib.pdf|
16     file:
17 \end{itemize}
18 \ix{LilyPond music typesetting software}
19
20 \noindent \includegraphics[scale=0.77]{gr-fib.pdf}
```

## AD. PHYSICS

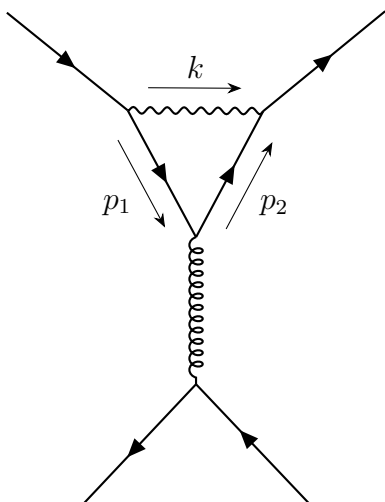
Feynman diagrams show what happens when elementary particles collide [122]. The Feynman diagrams below are from the *TikZ-Feynman: Feynman diagrams with TikZ* documentation [123]. **You must use `lualatex` instead of `pdflatex` to process documents that use the `tikz-feynman` package.**

The input in the documentation is different than here because a different random number generator is used [124]. I expect this to be corrected. In the meantime try replacing `vertical` with `vertical'` and/or switch some `fermion` to `anti fermion` lines [125].

```

1 \chapter{PHYSICS}
2 \ix{physics//Physics appendix}
3
4 Feynman diagrams\ix{Feynman diagram}
5 show what happens
6 when elementary particles collide
7 \cite{feynman-diagram}.
8 The Feynman diagrams below are from the
9 \citetitle{ellis2016} documentation \cite{ellis2016}.
10 \textbf{%
11   You must use \texttt{lualatex} instead
12   of \texttt{pdflatex}
13   to process documents that use the \texttt{tikz-feynman} package.%
14 }
15
16 The input
17 in the documentation
18 is different than here because a different random number generator
19 is used \cite{menke2019}.
20 I expect this to be corrected.
21 In the meantime try replacing \texttt{vertical}
22 with \texttt{vertical'}
23 and/or switch some \texttt{fermion}
24 to \texttt{anti} \texttt{fermion} lines \cite{ellis2017}.

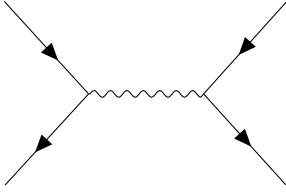
```



```

1 \feynmandiagram [large, vertical'=e to f] {
2   a -- [fermion] b -- [photon, momentum=(k)] c -- [fermion] d,
3   b -- [fermion, momentum=(p_1)] e -- [fermion, momentum=(p_2)] c,
4   e -- [gluon] f,
5   h -- [anti fermion] f -- [anti fermion] i,
6 };

```



```
1 \feynmandiagram [horizontal=a to b] {  
2   i1 -- [anti fermion] a -- [anti fermion] i2,  
3   a -- [photon] b,  
4   f1 -- [fermion] b -- [fermion] f2,  
5 };
```

## VITA

[Put a brief autobiographical sketch here.]

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