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A Collection of Packages

Notes Packages

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Some Documentation

Notes Packages

Willoughby Seago

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While at university I've been learning LaTeX. At the end of first year I wrote a package, called NotesPackage for use in second year, it was essentially just a preamble that I used in all documents. At the end of second year that package was a mess and I wrote an updated version, called NotesPackage2. Now almost at the end of third year it is again a mess and I am writing new packages. The idea this time is to separate different aspects into different packages which can be loaded together or individually. The three packages so far are NotesStyle, which controls how the document looks (this document is written with it), NotesBoxes which has a bunch of different box styles for various reasons, and NotesMaths, which is simply a lot of commands for typesetting maths. Since these packages are for my personal use they are subject to change at any point and definitely aren't stable. Everything in these packages has been done (probably better) in other packages so use those instead.

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Part I

The Packages

One

NotesMaths

The simplest of the packages is NotesMaths. It defines lots of commands that I use when writing maths. In this section these commands will be listed and examples given. Unless specified otherwise all commands in this chapter are math mode commands.

NotesMaths loads the following packages: amsfonts [1], amsmath [2], bm [3], and xparse [4].

1.1 Sets

1.1.1 Number Sets

In maths we often need to typeset various number sets. Most commonly the real numbers ($\mathbb{R}$), integers ($\mathbb{Z}$), complex numbers ($\mathbb{C}$), etc. The predefined sets (and a generic field) are

$$\text{Natural numbers:} \quad \mathbb{N}, \qquad \text{Integers:} \quad \mathbb{Z}, \tag{1.1}$$
$$\text{Rational numbers:} \quad \mathbb{Q}, \qquad \text{Real numbers:} \quad \mathbb{R}, \tag{1.2}$$
$$\text{Complex numbers:} \quad \mathbb{C}, \qquad \text{Quaternions:} \quad \mathbb{H}, \tag{1.3}$$
$$\text{Octonions:} \quad \mathbb{O}, \qquad \text{Field:} \quad \mathbb{F}. \tag{1.4}$$

Which can be accessed by

```
\naturals       \integers
\rationals      \reals
\complex        \quaternions
\octonions      \field
```

The default style for these sets, as we have already seen, is black board bold[1]. This can be changed, suppose you want upright bold number sets then by doing either of

```
\renewcommand{\numset}[1]{\mathbf{#1}}
\let\numset\mathbf
```

In which case the result will be

$$\text{Natural numbers:} \quad \mathbf{N}, \qquad \text{Integers:} \quad \mathbf{Z}, \tag{1.5}$$
$$\text{Rational numbers:} \quad \mathbf{Q}, \qquad \text{Real numbers:} \quad \mathbf{R}, \tag{1.6}$$
$$\text{Complex numbers:} \quad \mathbf{C}, \qquad \text{Quaternions:} \quad \mathbf{H}, \tag{1.7}$$
$$\text{Octonions:} \quad \mathbf{O}, \qquad \text{Field:} \quad \mathbf{F}. \tag{1.8}$$

[1] the precise font is actually from newtxmath which has three blackboard bold fonts [5]. This is the third which can be accessed as `\vvmathbb`.

1.1.2 Matrix Sets

As well as sets of numbers it is common to deal with sets of matrices. Typically these have understood names such as ‘the general linear group’, and predefined symbols to go along with them, in this case GL. The most general set of matrices is the set of all $m \times n$ matrices over a given field, $\mathbb{F}$[2]. There isn't a universally agreed upon standard notation for this, I have seen all of the following used:

$$\mathbb{F}_{m\times n}, \qquad \mathbb{F}^{m\times n}, \qquad \mathbb{F}^{m,n}, \qquad \text{and} \qquad \mathcal{M}_{m\times n}(\mathbb{F}). \tag{1.9}$$

[2]I suppose we could be even more general and consider matrices over a ring but this is about typesetting not maths so the distinction isn't important.

It is the last of these that I like the most as it fits with the notation of the other sets of matrices. Therefore this is the notation that I have implemented. To typeset $\mathcal{M}_{m\times n}(\mathbb{F})$ use

```
\matrices[m]{n}{\field}
```

If we leave off the optional argument, as in `\matrices{n}{\field}`, then we get $\mathcal{M}_n(\mathbb{F})$, which is understood as shorthand for $\mathcal{M}_{n\times n}(\mathbb{F})$, which are the square matrices. As well as these the following groups are defined: general linear group, special linear group, orthogonal group, special orthogonal group, unitary group, special unitary group. These are typeset using

```
\generalLinear    \specialLinear
\orthogonal       \specialOrthogonal
\unitary          \specialUnitary
```

and they will look like

$$\mathrm{GL}, \qquad \mathrm{SL}, \qquad \mathrm{O}, \qquad \mathrm{SO}, \qquad \mathrm{U}, \qquad \text{and} \qquad \mathrm{SU}\,. \tag{1.10}$$

There are also Lie algebra's of these sets which are typeset with

```
\generalLinearLie    \specialLinearLie
\orthogonalLie       \specialOrthogonalLie
\unitaryLie          \specialUnitaryLie
```

which produces

$$\mathfrak{gl}, \qquad \mathfrak{sl}, \qquad \mathfrak{o}, \qquad \mathfrak{so}, \qquad \mathfrak{u}, \qquad \text{and} \qquad \mathfrak{su}. \tag{1.11}$$

1.2 Bra-Ket Notation

In quantum mechanics it is customary to denote vectors by $|\psi\rangle$ and dual vectors by $\langle\varphi|$. These are called kets and bras respectively. We then write the inner product as $\langle\varphi|\psi\rangle$, which can be read as ‘bra-ket’ or ‘bracket’[3]. In this package there are four related commands and four starred versions. The commands are

[3]blame Paul Dirac

```
\ket{}    \bra{}    \braket{}{}    \ketbra{}{}
```

which, when given arguments, produce

$$|\psi\rangle, \qquad \langle\varphi|, \qquad \langle\varphi|\psi\rangle, \qquad \text{and} \qquad |\psi\rangle\langle\varphi|. \tag{1.12}$$

The starred versions of these commands,

```
\ket*{}    \bra*{}    \braket*{}{}    \ketbra*{}{}
```

produce the same but scale with their arguments. For example

$$\left|\frac{1}{2}\right\rangle, \qquad \left\langle\frac{1}{2}\right|, \qquad \left\langle\frac{1}{2}\middle|\frac{1}{2}\right\rangle, \qquad \text{and} \qquad \left|\frac{1}{2}\right\rangle\!\left\langle\frac{1}{2}\right|. \tag{1.13}$$

This is *not* the default behaviour because often we have arguments that are just slightly different in height and this produces multiple heights in the same equation. This is ugly. So the starred version is there only for when you explicitly want scaling.

1.3 Vectors

1.3.1 Vectors Proper

There are many notations for vectors. Some of the most common are

$$\vec{a}, \qquad \underline{a}, \qquad \overline{a}, \qquad \text{and} \qquad \boldsymbol{a}. \tag{1.14}$$

It is the last of these that I prefer and that is the default. The most basic vector command is `\vv{}` which is simply an alias for the `\bm` command from bm [3]. This can be redefined but it will typically cause issues. For example to redefine vectors to use an arrow above you would also have to think carefully about unit vectors with a hat. Speaking of unit vectors the following commands are all the vector commands defined:

```
\vv{x}        \vh{x}        \ve{x}
```

Which produce the following when given the argument `x`:

$$\boldsymbol{x}, \qquad \hat{\boldsymbol{x}}, \qquad \text{and} \qquad \boldsymbol{e}_{\boldsymbol{x}}. \tag{1.15}$$

Note that the command `\vv` is redefined if it is already defined. For example newtxmath [5] defines `\vv{AB}` to give $\overrightarrow{AB}$. This can still be accessed using `\OLDvv` in place of `\vv`.

1.3.2 Vector Calculus

To go along with vectors the four common vector calculus operators are defined, namely

```
\grad        \div        \curl        \laplacian
```

produce

$$\nabla, \qquad \nabla\cdot, \qquad \nabla\times, \qquad \text{and} \qquad \nabla^2. \tag{1.16}$$

Sometimes when working with multiple coordinate systems we use a subscript to denote which coordinate system the derivatives are with respect to. This can be achieved using the following

```
\grad[r]        \div[r]        \curl[r]        \laplacian[r]
```

which produce

$$\nabla_r, \qquad \nabla_r\cdot, \qquad \nabla_r\times, \qquad \text{and} \qquad \nabla_r^2. \tag{1.17}$$

Personally I prefer the basic undecorated ∇ for these but some people like to remind themselves that this is a vector[4]. For this use

```
\renewcommand{\nablaVector}{\vv{\nabla}}
\renewcommand{\nablaVector}{\vec{\nabla}}
```

which will give $\boldsymbol{\nabla}$ and $\vec{\nabla}$ respectively. This will automatically apply to the gradient, divergence, and curl, but not the Laplacian as that is a scalar operator. To change the Laplacian instead redefine `\nablaScalar`.

Sometimes one wishes to use the words grad, div, or curl, as operators, particularly when applied to objects other than standard $\mathbb{R}^n$ vectors. For this I have defined

```
\gradWord        \divWord        \curlWord
```

These produce

$$\operatorname{grad}, \qquad \operatorname{div}, \qquad \text{and} \qquad \operatorname{curl} \tag{1.18}$$

These are typeset using `\@diffWordOperator`[5] and so you can change this to change how they are all typeset. Don't forget to include `\mathop` for proper spacing! I haven't done this for Laplacian as I've never seen it used.

[4] it isn't.

[5] if using @ in a command you either need to be in a `.sty` file or it needs to be wrapped in `\makeatletter` and `\makeatother`

1.4 Calculus

1.4.1 Diffcoeff

The package diffcoeff [6] is loaded by NotesMath. The default symbol is changed to an upright "d" from italic. The command `\dd` is defined which produces output similar to `\dl` but with a default spacing of 2mu in front of the differential. For example,

```
\diff[n]{f}{x}    \diff*{\diffp{\mathcal{L}}{\dot{q}}}{t}
\dl{V} = \dl{x}\dd{y}\dd{z} = \dl{^3x_i}
```

produces

$$\frac{\mathrm{d}^n f}{\mathrm{d}x^n}, \qquad \frac{\mathrm{d}}{\mathrm{d}t}\frac{\partial \mathcal{L}}{\partial \dot{q}}, \qquad \mathrm{d}V = \mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z = \mathrm{d}^3 x_i \tag{1.19}$$

As well as these new derivatives are declared:

```
\diffm{\vv{u}}{t}    \diffD{y}{x}
```

which produce

$$\frac{\mathrm{D}\boldsymbol{u}}{\mathrm{D}t}, \qquad \frac{\Delta y}{\Delta x} \tag{1.20}$$

1.5 Miscellaneous

The commands in this section don't fit in any other section.

1.5.1 Absolute Value

The absolute value command is `\abs{x}` which produces $|x|$. This will automatically resize with its argument. There is a starred version, `\abs*`, which doesn't resize. The following uses `\abs` and `\abs*` respectively:

$$\left|\frac{1}{2}\right|, \qquad \text{and} \qquad |\frac{1}{2}|. \tag{1.21}$$

Note that the resizing behaviour is opposite to bra-ket notation. This is because I do want the default behaviour of `\abs` to be resizing.

1.5.2 Fourier Transforms

The symbol for a Fourier transform can be typeset using `\fourierTransform` which gives $\mathcal{F}$. Similarly `\inverseFourierTransform` gives $\mathcal{F}^{-1}$. Both of the Fs in these are typeset using `\fourierTransform` so changing the forward transform will automatically change the inverse transform.

1.5.3 Wordy Operators

The diagonal operator, diag, is used to define a diagonal matrix by simply listing the elements on the diagonal. It can be typeset using `\diag`.

The sign operator, sgn, returns the sign of its argument and can be typeset using `\sgn`.

The trig function $\operatorname{cosec} x = 1/\sin x$ is left out of LaTeXwhich uses csc instead. It can be typeset with `\cosec`. Similarly $\operatorname{cosech} x = 1/\sinh x$ can be typeset with `\cosech`

1.5.4 Averages

Two commonly used notations for the mean/expected value of a random variable, x, are $\overline{x}$ and $\langle x\rangle$. These can be typeset using `\mean{x}` and `\expected{x}` respectively. Additionally `\expected*` will resize with its argument. The following are typeset with `\expected` and `\expected*` respectively:

$$\langle\frac{1}{2}\rangle, \qquad \text{and} \qquad \left\langle\frac{1}{2}\right\rangle. \tag{1.22}$$

1.5.5 Operators

Operators in quantum mechanics are often denoted with a hat. This can be typeset using `\operator{O}` which produces $\hat{O}$. Sometimes operators can be seen as vectors, for example the angular momentum, in which case use `\vecoperator{L}` to produce $\hat{\boldsymbol{L}}$. This is also aliased as `\operatorvec`.

Two

NotesBoxes

The NotesBoxes package provides predefined boxes from the tcolorbox package [7].

NotesBoxes loads the following packages: listings [8], tcolorbox [7], xcolor [9] and xparse [4]. As well, the following tcolorbox libraries are loaded: skins, theorems, breakable, and hooks. It is also assumed that cleveref is loaded [10].

Much of the code for these boxes was taken from [11].

2.1 Important Box

The important box is the simplest box. It's use, as the name suggests, is to highlight important material. For example

```
\begin{important}
    The volume element in three dimensions is
    \begin{equation}
        \dd{V} = \dd{x}\dd{y}\dd{z}
        = r^2\sin\vartheta \dd{r}\dd{\vartheta}\dd{\varphi}
    \end{equation}
\end{important}
```

produces

> The volume element in three dimensions is
>
> $$\mathrm{d}V = \mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z = r^2 \sin\vartheta\,\mathrm{d}r\,\mathrm{d}\vartheta\,\mathrm{d}\varphi. \tag{2.1}$$

2.2 Theorem Box

The theorem box is for typesetting theorems and their proofs. For example

```
\begin{thm}{}{}
    There are infinitely many primes.
    \begin{proof}
        Suppose there is a finite number of primes, \(\{p_i\}\).
        Then \(\prod_i p_i + 1\) is either a new prime or has a
        prime factor not in \(\{p_i\}\).
        Therefore there are an infinite number of primes.
    \end{proof}
\end{thm}
```

produces

Theorem 2.2. There are infinitely many primes.

Proof. Suppose there is a finite number of primes, $\{p_i\}$. Then $\prod_i p_i + 1$ is either a new prime or has a prime factor not in $\{p_i\}$. Therefore there are an infinite number of primes. □

Notice the two empty arguments. The first of these is for assigning a title to the theorem. The second is for assigning a label. This pattern follows for the rest of the boxes so won't be mentioned again. For example,

```
\begin{thm}{Title}{thm:label}
    A theorem.
\end{thm}
```

produces

Theorem 2.3 — Title. A theorem.

which we can then reference using `\cref{thm:label}` or `\nameref{thm:label}` which produces Theorem 2.3 or Title respectively.

2.3 Almost Theorem Boxes

Often a result is not important enough to achieve the name of theorem. Instead such results are called claims, propositions, lemmas, or corollaries. There are boxes for these.

```
\begin{clm}{}{}
    This is true.
    \begin{proof}
        Just believe me.
    \end{proof}
\end{clm}
```

produces

Claim 2.4 This is true.

Proof. Just believe me. □

and

```
\begin{prp}{}{}
    A thing that we think is true.
    \begin{proof}
        Trivial.
    \end{proof}
\end{prp}
```

produces

Proposition 2.5 A thing that we think is true.

Proof. Trivial. □

A lemma can be produced using

```
\begin{lma}{Jordan's Lemma}{lma:Jordan's lemma}
    Let \(f\) be a continuous complex function
    defined on the semicircle,
    \begin{equation}
        C_R = \{Re^{i\vartheta} \vert \vartheta \in [0, \pi]\},
    \end{equation}
    which has radius \(R > 0\) with the semicircle lying in the
    upper half plane and centred at the origin.
    If we can write \(f(z) = e^{iaz}g(z)\) for \(z\in C_R\) then
    \begin{equation}
        \abs{\int_{C_R} f(z) \dd{z}} \le \frac{\pi}{a}M_R
    \end{equation}
    where
    \begin{equation}
        M_R \coloneq \max_{\vartheta \in [0, \pi]}
        \abs{g(Re^{i\vartheta})}.
    \end{equation}
    \begin{proof}
        Left to the reader.
    \end{proof}
\end{lma}
```

which produces

Lemma 2.6 — Jordan's Lemma Let f be a continuous complex function defined on the semicircle,

$$C_R = \{Re^{i\vartheta} | \vartheta \in [0, \pi]\}, \tag{2.7}$$

which has radius $R > 0$ with the semicircle lying in the upper half plane and centred at the origin. If we can write $f(z) = e^{iaz}g(z)$ for $z \in C_R$ then

$$\left| \int_{C_R} f(z)\, \mathrm{d}z \right| \le \frac{\pi}{a} M_R \tag{2.8}$$

where

$$M_R \coloneq \max_{\vartheta \in [0,\pi]} \left| g(Re^{i\vartheta}) \right|. \tag{2.9}$$

Proof. Left to the reader. □

Similarly one may consider a corollary

```
\begin{crl}{}{}
    Let \(f(z) = 1/z\).
    Then
    \begin{equation}
```

```
        \int_{C_R} f(z) \dd{z} = 0
    \end{equation}
    where \(C_R\) is the semicircle of radius \(R\) in the upper half plane.
    Then
    \begin{equation}
        \lim_{R \to \infty} \int_{C_R} f(z) \dd{z} = 0.
    \end{equation}
    \begin{proof}
        The proof follows immediately from \nameref{lma:Jordan's lemma}.
    \end{proof}
\end{crl}
```

produces

Corollary 2.10 Let $f(z) = 1/z$. Then

$$\int_{C_R} f(z)\, \mathrm{d}z = 0 \tag{2.11}$$

where C_R is the semicircle of radius R in the upper half plane. Then

$$\lim_{R\to\infty} \int_{C_R} f(z)\, \mathrm{d}z = 0. \tag{2.12}$$

Proof. The proof follows immediately from Jordan's Lemma. □

2.4 Definitions

When defining something the box to use is the definition box.

```
\begin{dfn}{Group}{}
    A group, \(\langle G, \cdot \rangle\) is a set, \(G\),
    and binary operation, \(\cdot\colon G\times G \to G\),
    which satisfies the following group axioms:
    \begin{align}
        \forall a, b, c\in G \vert a(bc) = (ab)c,\\
        \exists e \in G \vert eg = ge = e \forall g\in G,\\
        \forall g \in G \exists g^{-1} \in G \vert
        gg^{-1} = g^{-1}g = e.
    \end{align}
\end{dfn}
```

produces

Definition 2.13 — Group A group, $\langle G, \cdot\rangle$ is a set, G, and binary operation, $\cdot\colon G \times G \to G$, which satisfies the following group axioms:

$$\forall a, b, c \in G \vert a(bc) = (ab)c, \tag{2.14}$$

$$\exists e \in G \vert eg = ge = e \forall g \in G, \tag{2.15}$$

$$\forall g \in G \exists g^{-1} \in G \vert gg^{-1} = g^{-1}g = e. \tag{2.16}$$

We may wish to introduce some new notation. This can be done with the notation box:

```
\begin{ntn}{}{}
    We write \(A \cong B \iff \) \(A\) is isomorphic to \(B\).
\end{ntn}
```

produces

Notation 2.17 We write $A \cong B \iff A$ is isomorphic to B.

2.5 Additional Material Boxes

Suppose we wish to give an example. Then we can use the example box:

```
\begin{exm}{}{}
    The set \(\integers/2\integers = \{0, 1\}\)
    forms a group under addition modulo 2.
\end{exm}
```

■ **Example 2.18** The set $\mathbb{Z}/2\mathbb{Z} = \{0, 1\}$ forms a group under addition modulo 2.

Or suppose that we want to note an application of what we have derived. Then we can use the application box.

```
\begin{app}{}{}
    Groups are useful in physics as they describe the
    symmetries of an object
\end{app}
```

■ **Application 2.19** Groups are useful in physics as they describe the symmetries of an object

2.6 Code Boxes

If we want to display code then we can do this in a code block.

```
\begin{cde}{}{}
    \begin{lstlisting}[language=python, gobble=12]
        def foo(x):
            print(f"x = {x}")
    \end{lstlisting}
\end{cde}
```

produces

■ **Code 2.20**

```python
def foo(x):
    print(f"x = {x}")
```

The code is typeset using the `lstlistings` environment from the listings package so see [8] for more details on that. Note that the `gobble=n` keyword removes the first `n` characters. In my document I have 12 spaces of indentation within the `lstlisting` environment and so they are removed by `gobble`.

The colour scheme is based on the solarized colour scheme [12]. It should work for multiple languages. For example

```
\begin{cde}{}{}
    \begin{lstlisting}[language=C++, gobble=12]
        #include <iostream>
        template <typename T>
        void foo(T x) {
            std::cout << "x = " << x << std::endl;
        }
    \end{lstlisting}
\end{cde}
```

produces

Code 2.21

```
#include <iostream>
template <typename T>
void foo(T x) {
    std::cout << "x = " << x << std::endl;
}
```

and

```
\begin{cde}{}{}
    \begin{lstlisting}[language={[LaTeX]TeX}, gobble=12]
        \newcommand{\foo}[1]{#1}
    \end{lstlisting}
\end{cde}
```

produces

Code 2.22

```
\newcommand{\foo}[1]{#1}
```

2.7 Remark and Warn Boxes

Often we wish to make a note of something without breaking the flow or maybe draw attention to an important point. For this we have the remark and warn boxes. For example

```
\begin{rmk}
    Notice that ...
\end{rmk}
```

produces

R Notice that ...

Similarly

```
\begin{wrn}
    Be careful not to ...
\end{wrn}
```

produces

! Be careful not to ...

We can put boxes in boxes. This is most useful when putting remarks, warnings, or important boxes in other boxes. For example

■ **Example 2.23** This is an example

R This is a remark

Lemma 2.24 This is a lemma

! This is a warning

Theorem 2.25. This is a theorem

This is important

In theory we can go multiple levels deep but this starts to look silly.

Definition 2.26 If we have long boxes they should automatically break over the page. For example this definition has a list of properties:

1. First property
2. Second property
3. Third property

and lots of text which means it takes more space than is left on the page.
Lets test this by making the text in this box so long that it has no choice but to break into two parts. It's becoming hard to think of something to say so I'm just going to use lorem ipsum.
Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas

a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.
Hey Look! We're on the next page.

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