Theorems, Derivations, and Notation

STEM Track — Session 4 of 5

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Today

1. Theorem environments and proofs

Everything today goes into the final project you brought from Session 3.

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2. The `align` family

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3. Matrices, `cases`, and delimiters

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2. The `align` family
3. Matrices, `cases`, and delimiters
4. Fonts, operators, and notation
5. `cleveref`: referencing at scale

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SECTION 1

Theorems and Proofs

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- A numbered, cross-referenceable object like a figure, a table, or an equation.
- Once it is a structure, insertion, renumbering, and referencing become free.

The setup

TYPE ALONG

```
\usepackage{amsthm}

\newtheorem{theorem}{Theorem}[section]
\newtheorem{lemma}[theorem]{Lemma}
\newtheorem{corollary}[theorem]{Corollary}

\theoremstyle{definition}
\newtheorem{definition}[theorem]{Definition}
\newtheorem{example}[theorem]{Example}
```

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- `\theoremstyle` before a declaration picks the look: `plain` (italic body), `definition` (upright), `remark` (lighter).
- `\newtheorem*` gives an unnumbered environment.

Using it

```
\begin{theorem}[Bolzano--Weierstrass] \label{thm:bw}
    Every bounded sequence in $\mathbb{R}^n$ has a
    convergent subsequence.
\end{theorem}

\begin{proof}
    Bisect, select, and diagonalise.
\end{proof}
```

- The optional argument is the name, printed in parentheses.

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- `proof` supplies "*Proof.*" and the QED square itself.

SECTION 2

The align Family

“Several equations” means different things

Environment	Use it when
`equation`	one numbered equation
`align`	separate equations, aligned, *each* numbered
`gather`	separate equations, centred, no alignment
`split`	one derivation across lines, *one* number
`multline`	one very long equation, ssplit across lines

One number: split

TYPE ALONG

```
\begin{equation} \label{eq:area}
\begin{split}
    A &= \int_0^1 (x^3 + 3x^2 + 3x + 1)\, dx \\
      &= \frac{1}{4} + 1 + \frac{3}{2} + 1 \\
      &= \frac{15}{4}
\end{split}
\end{equation}
```

- split goes inside equation.

One number: split

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\end{split}
\end{equation}
```

- `split` goes inside `equation`.
- `&` marks the alignment point

Many numbers: `align`

```
\begin{align}
    \nabla \cdot \mathbf{E} &= \frac{\rho}{\varepsilon_0}
        \label{eq:gauss} \\
    \nabla \times \mathbf{B} &= \mu_0 \mathbf{J}
        \label{eq:ampere}
\end{align}
```

- Each line is a separate equation you may reference separately.

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- Each line is a separate equation you may reference separately.
- `\notag` suppresses the number on any one line.

Text inside a derivation

```
\begin{align}
    f(x) &= (x+1)^2 \\
    \intertext{expanding the square,}
         &= x^2 + 2x + 1
\end{align}
```

- `\intertext` interrupts for a line of text without losing the alignment.

SECTION 3

Matrices and Cases

Matrices

```
\[
\begin{pmatrix} a & b \\ c & d \end{pmatrix}
\quad
\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}
\quad
\begin{vmatrix} a & b \\ c & d \end{vmatrix}
\]
```

`pmatrix`	( )	`bmatrix`	[ ]
`vmatrix`	determinant bars	`Vmatrix`	norm bars

Piecewise definitions

```
\[
f(x) =
\begin{cases}
    x^2  & \text{if } x \geq 0, \\
    -x   & \text{if } x < 0.
\end{cases}
\]
```

Note that the trailing spacce has to go inside the text command because spaces are ignored by math mode.

SECTION 4

Fonts and Operators

Maths fonts

```
$\mathbb{R}, \mathbb{Z}, \mathbb{C}$     % number sets
$\mathcal{L}, \mathcal{O}, \mathcal{F}$ % script
$\mathbf{v}, \mathbf{A}$                % bold
$\mathrm{d}x$                           % upright
```

- `\mathbb` works on **uppercase only**

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- `\mathbb` works on **uppercase only**
- `\mathbf` is upright bold.

Custom operators

```
Wrong:  $Tr(AB) = Tr(BA)$

% preamble
\DeclareMathOperator{\Tr}{Tr}
\DeclareMathOperator*{\argmin}{arg\,min}

% body
Right:  $\Tr(AB) = \Tr(BA)$
        $\hat{\theta} = \argmin_{\theta} L(\theta)$
```

- Same logic as `\log` in Session 3: an operator name is not a product of variables.

The `physics` package

```
\usepackage{physics}

\dv{f}{x}       \pdv{f}{x}      \pdv[2]{f}{x}
\grad  \curl    \abs{x}         \norm{v}
\bra{\psi}      \ket{\phi}      \braket{\psi}{\phi}
```

- All of this can be written by hand but the physics package makes life easier by compressing them into single commands

SECTION 5

cleveref

The problem `\ref` leaves open

- `\ref` gives you the number but you have to type out if it's a theorem or otherwise manually and if your theorem becomes a lemma then your day gets ruined.

TYPE ALONG

```
\usepackage{hyperref}
\usepackage{cleveref}       % load AFTER hyperref

\cref{thm:bw}               % -> theorem 3.1
\Cref{thm:bw}               % -> Theorem 3.1
\cref{eq:gauss,eq:ampere}   % -> eqs. (5) and (6)
```

- The word comes from the label's counter so if you rename your environment then all of your references get updated.

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- Multiple references get sorted and compressed for you.

SECTION 6

Exercise

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Upgrade your final project

1. A theorem–proof pair (engineers: definition–example) that is correctly numbered, labelled, and has the QED placed properly.
2. One derivation of three or more lines with `split`, under one number.
3. One `cases` definition or one matrix expression.
4. Two custom operators to be used in the project.
5. Convert every `\ref` to `\cref`.

SECTION 7

Homework

Bring to Session E2

Three things

A small `.csv` dataset from your own work
One diagram you currently draw by hand or in PowerPoint
A function that is about 10-30 lines
Session E2 typesets all three properly.

Questions?

https://www.overleaf.com/learn • https://tex.stackexchange.com