Writing Class 5: LaTeX, Figures, Tables, and Visual Communication

Mathematical Modeling Lecture

Mathematical Modeling

Kenneth Sok Kin Cheng

Session Route

Launch	Build	Test
Question Motivating context, key vocabulary, and the first modelling decision.	**Method** Worked example, diagram or table, calculation, and parameter meaning.	**Critique** Checkpoint practice, limitation check, and communication of results.

Columns are used where comparison helps; explanation slides stay clean and spacious.

From Words to Pages

Core explanation, worked reasoning, and application

From Words to Pages

In W1–W4 we developed structure, content, and language. This final class is about the *presentation* of all of that on the page: how a paper is typeset, how figures and tables are made, and how a team's workflow makes everything come together at the submission deadline.
There are two reasons to take this seriously:

- Visual quality is part of the *Communication* pillar of the rubric. A well-typeset paper with clear figures *looks* like an Outstanding paper before the judge has read a single sentence.
- In the final 24 hours of a competition, integration issues (figures not exporting, references broken, page count overflow) consume disproportionate time. A team that has practised the tools in advance can use those hours for content; a team that has not will spend them debugging the document.

This class will not turn anyone into a typography expert. Its purpose is to establish a competent baseline, identify the highest-leverage visual choices, and lock in a workflow that survives competition stress.

LaTeX: The Competition Standard

Core explanation, worked reasoning, and application

LaTeX: The Competition Standard

LaTeX is the de facto standard for mathematical-modeling competition papers. We recommend it for three reasons:

- **Mathematical typesetting.** Equations look professional with no extra effort. Word-processor equations are flagged immediately by judges.
- **Cross-references.** Equations, figures, tables, and citations stay linked correctly through rewrites and reorderings.
- **Templates.** Mature templates exist for IMMC, HiMCM, MCM that handle layout decisions for you.

Method: Method: Setting Up Overleaf for a Competition

1. Create a single shared Overleaf project before the competition starts. All teammates should be added as collaborators.
2. Start from a known-good template (IMMC, HiMCM, or MCM-style; many examples exist on Overleaf's template gallery).
3. In the first hour of the competition, finalise:
   - Document class, font size, margin settings.
   - Section structure (insert empty sections with placeholders).
   - Citation style (use BibTeX, not manual references).
4. Set up auto-compile on save, and commit to a single "main" file structure.

Warning: Warning: Common Overleaf Pitfalls

- **Compilation timeout.** Overleaf free tier limits compile time. Heavy TikZ figures may time out. Compile externally (TeX Live) if you anticipate problems.
- **Concurrent edits on the same line.** Coordinate via teammates rather than via Overleaf's auto-merge — it sometimes loses content silently.
- **Version history.** Keep an external backup (a daily download of the source as a zip) in case Overleaf has an outage at submission time.

Code or LaTeX example: A Minimal Preamble for a Modeling Paper

Listing 1: A clean preamble adequate for any IMMC/HiMCM paper.

```
\documentclass[12pt,a4paper]{article}
\usepackage[margin=2.5cm]{geometry}
\usepackage{amsmath, amssymb, amsthm}
\usepackage{graphicx}        % include figures
\usepackage{booktabs}        % nicer tables (\toprule, \midrule, \bottomrule)
\usepackage{caption}         % better caption formatting
\usepackage{subcaption}      % side-by-side subfigures
\usepackage{float}           % stricter figure placement (H option)
\usepackage{hyperref}        % clickable references
\usepackage{cleveref}        % "Fig. 1" instead of just "1" in cross-refs
\usepackage[numbers]{natbib} % numerical citation style

\title{Team N12345: Modeling the Throughput of\\
       a Coffee Shop Queue}
\author{}                    % no individual names, per contest rules
\date{November 2026}
```

Note: On font size and margins

Contest rules specify font size (usually 12pt) and margins. Verify before the competition. The most common defaults are 12pt Times New Roman or Computer Modern, 1-inch margins. Do *not* shrink either to gain space; judges check.

Method: Method: Mathematics That Reads Well

1. **Display long equations; inline short ones.** An equation that names quantities and will be referenced later (`\label`, `\ref`) goes on its own line in an `equation` environment. A short relation like $x \geq 0$ goes inline.
2. **Number every equation you reference.** Use `equation` with `\label`; reference with `\eqref` or `Cref`. Equations cited zero times can be `equation*` (un-numbered).
3. **Punctuate displayed equations as parts of sentences.** An equation that ends a sentence ends with a period. An equation followed by “where” or “and” ends with a comma.

Worked Example: Example 1: Punctuated Displayed Equations

The dynamics are governed by

$$\frac{dS}{dt} = -\beta SI, \qquad \frac{dI}{dt} = \beta SI - \gamma I, \tag{1}$$

where β is the infection rate and γ the recovery rate. Eq. (1) is the classical SIR system, named in Section 4.

Note: the comma after the second equation, the "where" clause that explains symbols, and the cross-reference `Eq.\ \eqref{eq:sir}`. This is the conventional style.

Figures: The Single Most Underrated Investment

Core explanation, worked reasoning, and application

Figures: The Single Most Underrated Investment

A single well-made figure can communicate a key insight more effectively than three pages of text. Conversely, a sloppy figure tells the judge you ran out of time — or worse, that you don't understand your own model.

Method: Method: The Five Criteria for a Publication-Quality Figure

Every figure in your paper should satisfy:

1. **Self-contained.** A reader who skips the body and looks only at the figure plus caption should understand what the figure shows.
2. **Labelled axes with units.** “Time” is not a label; “Time (s)” or “Time (days)” is.
3. **Legend present.** Multiple curves on one plot need a legend distinguishing them.
4. **Readable text.** Tick labels and legends should be readable at the printed size (typically 10pt minimum).
5. **Honest scales.** Linear scale by default; logarithmic only when there is a reason (range spans orders of magnitude, or theory predicts a power law). Never truncate axes to exaggerate differences.

Note: On colour

Use colour sparingly and meaningfully. Greyscale plus one accent colour (often a dark blue or burgundy) is sufficient for most figures. Avoid rainbow colour schemes; they imply ordering even where none exists, and they fail under greyscale printing.

For technical reasons many judges print papers in greyscale. *Your figures must remain interpretable in greyscale.* Distinguish curves by line style (solid, dashed, dotted) as well as by colour.

Method: Method: Writing a Strong Caption

A figure caption should:

1. Start with a **short label phrase** that names the figure (often a sentence fragment, period-terminated).
2. Continue with one or two sentences of explanation.
3. Identify the **key takeaway** the reader should see.
4. Always end with a period.

Worked Example: Example 2: Strong vs Weak Captions

Weak: “Figure 3: Simulation results.”
Problem: Says nothing. Does not stand alone.
Weak: “Figure 3: Number of customers vs. time.”
Problem: Better, but still does not say what the reader should conclude.
Strong: “Figure 3: Customers in the queue over a simulated 4-hour service window. Peak queue length of 17 occurs around minute 90 and remains above 10 from minute 60 to minute 120, supporting the recommendation to deploy a second server during this period.”
Why it works: Names what the figure is, what the reader should observe (peak around 90, sustained above 10), and connects to the recommendation. A judge skimming captions still gets the headline result.

Method: Method: Recommended Tools by Figure Type

Figure type	Recommended tool
Time series / scatter / regression	Python `matplotlib` or Excel; export PDF or PNG at 300+ dpi.
Bar / pie / tornado	Python `matplotlib`; or Excel with care taken to clean the default style.
Network diagrams	TikZ (for full integration), or Graphviz / NetworkX.
Schematics / flow charts	TikZ; or Inkscape; or `draw.io` (export to SVG/PDF).
Mathematical diagrams (with formulas)	TikZ exclusively.
3D surfaces	`matplotlib`'s `Axes3D`, or `plotly`; consider showing a 2D contour plot instead.
Maps	QGIS or Python `geopandas`; for simple maps, manual TikZ.

Code or LaTeX example: Tools for Generating Figures

Listing 2: A minimal matplotlib snippet that produces a paper-quality figure.

```
import matplotlib.pyplot as plt
import numpy as np

t = np.linspace(0, 50, 500)
beta, gamma = 0.4, 0.1
# (SIR solution omitted; use scipy.integrate.solve_ivp)

fig, ax = plt.subplots(figsize=(6, 4))
ax.plot(t, S, label='Susceptible',  color='black', linestyle='-')
ax.plot(t, I, label='Infected',     color='black', linestyle='--')
ax.plot(t, R, label='Recovered',    color='black', linestyle=':')
ax.set_xlabel('Time (days)')
ax.set_ylabel('Number of individuals')
ax.set_title('Time evolution of an SIR epidemic ($\\beta=0.4$, $\\gamma=0.1$)')
ax.legend
ax.grid(True, alpha=0.3)
plt.tight_layout
plt.savefig('sir_dynamics.pdf', dpi=300, bbox_inches='tight')
```

Note: Why `savefig` settings matter

`dpi=300` ensures sharpness on print. `bbox_inches='tight'` prevents whitespace around the figure. Saving as PDF (vector) is preferred over PNG (raster) for line plots; PNG is appropriate only for images that are inherently rasterised (photographs, satellite images).

Tables: Often Better Than Figures

Core explanation, worked reasoning, and application

Tables: Often Better Than Figures

If you have exactly four data points to compare across three categories, a table is almost always clearer than a figure. Tables are underused in competition papers because students learn early that “figures are more impressive”. Judges, in fact, value tables: they let the reader see the actual numbers.

Method: Method: Five Rules for Strong Tables

1. **Use `booktabs`.** The `\toprule`, `\midrule`, `\bottomrule` commands produce typographically correct horizontal rules. Vertical rules look amateur; avoid them.
2. **Units in column headers, not in every cell.** "Time (s)" as a header is better than "5.2 s" in every row.
3. **Consistent decimal places** in numerical columns. "5.20" looks better than "5.2" in a column where most entries have two decimals.
4. **Right-align numbers; left-align text.** Aligned decimal points make comparison visual.
5. **Caption above the table.** Unlike figures (caption below), tables conventionally carry their caption above.

Worked Example: Example 3: A Strong Table

Validation of the queuing model: predicted vs simulated average wait times across four arrival-rate scenarios.

Arrival rate λ (/hr)	Predicted W_q (min)	Simulated W_q (min)	Relative error
8	0.67	0.65	-3.0%
10	1.33	1.31	-1.5%
12	4.00	3.94	-1.5%
14	18.67	18.21	-2.5%

Caption above the table; `booktabs` *rules; aligned decimals; units in headers.*

Multi-Panel Layouts

For figures with two or three related panels (e.g., baseline vs intervention), use `subcaption` for proper labelling (a), (b), (c).

Code or LaTeX example: Multi-Panel Layouts

Listing 3: A two-panel figure with sub-captions.

```
\begin{figure}[H]
    \centering
    \begin{subfigure}[t]{0.45\textwidth}
        \includegraphics[width=\textwidth]{baseline.pdf}
        \caption{Baseline configuration ($N=1$ server).}
        \label{fig:baseline}
    \end{subfigure}
    \hfill
    \begin{subfigure}[t]{0.45\textwidth}
        \includegraphics[width=\textwidth]{intervention.pdf}
        \caption{Two-server configuration.}
        \label{fig:intervention}
    \end{subfigure}
    \caption{Queue dynamics under (a) baseline staffing and (b) the recommended two-server
     intervention. The peak queue length drops by 76\% under intervention.}
    \label{fig:queue-comparison}
\end{figure}
```

Cross-References, Citations, and the Bibliography

Core explanation, worked reasoning, and application

Method: Method: Use `cleveref` for Cross-References

- Label every figure, table, equation, and section that you intend to reference.
- Use `\cref` from `cleveref`; it automatically picks the right word: “Fig. 3”, “Table 2”, “Eq. (5)”, “Section 4”.
- Never write “see the figure above” — after a rewrite, “above” may no longer be true. Always reference by number.

Method: Method: Citation Practice

1. Use BibTeX. Maintain a single `references.bib` file.
2. For each citation, capture: author, title, journal/conference/publisher, year, volume/pages, DOI/URL.
3. Cite at the point of claim: "...logistic growth (Murray, 2002)" or "...Murray [3] develops this further".
4. Include 4–10 references for an IMMC paper. Fewer than 4 reads as isolation; more than 15 (without good reason) reads as padding.

Note: On citation style

Use IEEE numerical or APA author-date; pick one and be consistent. The choice matters less than consistency. Common acceptable sources:

- **Textbooks.** Giordano *A First Course in Mathematical Modeling*; Hillier & Lieberman *Introduction to Operations Research*; Bertsekas *Nonlinear Programming*.
- **Peer-reviewed papers.** Search via Google Scholar; verify the journal exists.
- **Government / authoritative sources.** Census data, WHO, transport authorities — cite the URL and access date.
- **Wikipedia.** Acceptable for definitions only; for any substantive claim, find the underlying source Wikipedia cites and cite that instead.

The Submission-Day Workflow

Core explanation, worked reasoning, and application

The Submission-Day Workflow

The final 6–12 hours of a competition are not for new analysis; they are for integration, polishing, and submission. A team that has rehearsed the workflow finishes calmly; one that has not, finishes in panic.

Method: Method: A Rehearsable Final-Day Workflow

1. **T-12 hours:** Freeze the modeling. No new models from this point. All effort goes to writing and presentation.
2. **T-12 to T-8:** Polish prose pass. Apply W4 techniques. One teammate is the dedicated polisher.
3. **T-10 to T-6:** Finalise figures and tables. Regenerate any low-resolution images; verify captions; cross-check numbers between figures and text.
4. **T-8 to T-4:** Verify cross-references. Use `\cref`; ensure every Fig./Tab./Eq./Sec. number renders.
5. **T-4 to T-2:** Rewrite the Summary one last time (see W2). This deserves its own dedicated session.
6. **T-2 to T-1:** Bibliography check, spell check, page-count check (HiMCM has page limits; IMMC has soft conventions).
7. **T-1 to T-0.5:** Compile final PDF. Verify it opens correctly on a different machine.
8. **T-0.5:** Submit. *Never* aim for the deadline; aim to submit half an hour early.

Warning: Warning: The Common Final-Hour Failures

Each of these has cost real teams their submission:

- **LaTeX compilation timeout** from a heavy TikZ figure introduced late. *Solution:* compile after every major addition; never add a 500-line TikZ figure in the last hour.
- **Bibliography format errors** that look fine in the editor but break the compile. *Solution:* compile the bibliography on Day 2, not Day 4.
- **Page-count overflow** discovered too late. *Solution:* monitor page count daily; tighten language preemptively.
- **File-name violations** (contest requires Team_ID_Problem_X.pdf; team submits paper.pdf). *Solution:* read the submission rules at hour 1 and again at hour T-2.
- **Internet outage during submission.** *Solution:* submit early. Always have a backup of the PDF on a personal device.

Method: Method: Role Allocation for the Final Phase

A 4-person team should explicitly assign final-phase roles:

- **Polisher:** reads every section line-by-line for prose quality. The strongest writer.
- **Validator:** re-checks every number, equation, and figure caption against the source.
- **Submitter:** handles compilation, file naming, and the submission portal. Owns the deadline.
- **Floater:** handles whatever comes up; final read of the Summary; sanity checks.

A 2–3 person team merges these. The important point: the roles are explicit, not implicit. Otherwise multiple people end up doing the same thing while no-one fixes the bibliography.

Workshop Exercises

Core explanation, worked reasoning, and application

Exercises: Exercise W5.1: Build a Template

Before any practice runs, build a complete LaTeX template containing all section headings, dummy variables/captions, and your team's intended formatting. The template should compile cleanly out of the box with no warnings. Save it; reuse it for every practice.

Exercises: Exercise W5.2: Reproduce a Strong Figure

Find one figure from an Outstanding paper that you think is exceptional. Recreate it in Python `matplotlib` or TikZ from scratch. Match every element: axes, units, font sizes, legend placement, colour. This is the fastest way to learn what publication-quality looks like.

Exercises: Exercise W5.3: Write Five Captions

For each of the following hypothetical figures, write a paper-quality caption (1–3 sentences):

1. A scatter plot of car arrivals over a day, fitted by a Poisson model.
2. A tornado diagram of sensitivity to five parameters.
3. A network graph showing the proposed bicycle highway routes.
4. A heatmap of predicted commute times across the city.
5. Side-by-side simulated outcomes (baseline / intervention).

Exercises: Exercise W5.4: Mock Submission

Run a one-hour mock submission drill. Starting from a known LaTeX project:

- Add one new figure, one new equation, one new section.
- Re-verify all cross-references.
- Recompile cleanly.
- Rename the file according to a (made-up) contest naming convention.
- Upload to a shared drive folder named “submission”.

Time each step. The full drill should take under one hour; any step that takes longer is a process problem to fix before the real competition.

Exercises: Exercise W5.5: Find Three Visual Improvements in Your Paper

Take your most recent practice paper. Identify three visual choices that could be improved: a figure that needs a better caption, a table that should use `booktabs`, an equation that should be displayed instead of inline, etc. Implement the fixes and check that the paper still compiles.

Closing the Writing Class

Core explanation, worked reasoning, and application

Note: The Five-Class Arc

1. **W1:** The four pillars of the rubric, the standard paper structure, the way Outstanding papers read.
2. **W2:** The Summary: the single most important page.
3. **W3:** Assumptions, Validation, Sensitivity — the trust chain.
4. **W4:** English academic writing style, voice, hedging, connectives, Chinglish patterns.
5. **W5:** LaTeX, figures, tables, the submission workflow.

Closing the Writing Class

The five classes amount to roughly thirty hours of work to internalise. By comparison, learning a new modeling method (regression, simulation, optimisation) takes longer and contributes a smaller share of the score. Writing is the most leverage-rich investment the team can make.

Note: Three Pieces of Final Advice

1. **Read at least three Outstanding papers before your first competition.** Nothing else compresses learning so quickly.
2. **Practise the workflow under time pressure.** A two-day mock submission a month before the real competition reveals every weak link.
3. **Designate the polisher early.** The teammate who will be responsible for prose quality should know that role from Day 1. They should keep the W4 reference sheet open.

Closing the Writing Class

The Writing Class ends here. The next step — the only step that matters now — is to write papers. Many papers. Imperfect papers. Improved papers. Polished papers. Submitted papers.

Appendix A: One-Page Compilation Checklist

Core explanation, worked reasoning, and application

Appendix A: One-Page Compilation Checklist

- ☐ Document compiles with no errors and no critical warnings.
- ☐ All cross-references resolve (no “Fig. ??”).
- ☐ Page count within contest limit (HiMCM: 25 pages; IMMC: check yearly).
- ☐ Font and margin per contest rules.
- ☐ Team ID on every page (if required).
- ☐ Page numbers visible.
- ☐ Title page formatted per contest.
- ☐ Summary on its own page (one page).
- ☐ All figures captioned (caption below figure).
- ☐ All tables captioned (caption above table).
- ☐ All equations referenced from text are numbered.
- ☐ Bibliography in consistent style (APA, IEEE, etc.).
- ☐ File named per contest convention.
- ☐ PDF opens correctly on a non-team machine.
- ☐ Upload completed at least 30 minutes before deadline.

Appendix B: A Minimal Template Snippet

Core explanation, worked reasoning, and application

Code or LaTeX example: Appendix B: A Minimal Template Snippet

```
\documentclass[12pt,a4paper]{article}
\usepackage[margin=2.5cm]{geometry}
\usepackage{amsmath, amssymb, amsthm, graphicx, booktabs,
            caption, subcaption, float, hyperref, cleveref}
\usepackage[numbers]{natbib}

\title{Team N12345: [Your Paper Title]}
\author{}
\date{}

\begin{document}


\begin{abstract}
\end{abstract}

\section{Introduction}
\section{Assumptions and Notation}
\section{Model Development}
\section{Results}
\section{Validation}
\section{Sensitivity Analysis}
\section{Strengths and Weaknesses}
\section{Conclusion}
```

Code or LaTeX example: Appendix B: A Minimal Template Snippet

```
\bibliographystyle{IEEEtran}
\bibliography{references}

\appendix
\section{Code Listing}

\end{document}
```

Appendix C: Tools Quick-Reference

Core explanation, worked reasoning, and application

Appendix C: Tools Quick-Reference

Task	Tool
LaTeX editor	Overleaf (online, free tier sufficient); TeXstudio (local).
Version control	Overleaf's Git integration; or Git + GitHub if working locally.
Figure generation	Python `matplotlib`; TikZ for math diagrams.
Data analysis	Python `pandas`, `numpy`, `scipy`.
Reference management	BibTeX + `references.bib`.
Spell-check	Overleaf's built-in; or pass through Grammarly.
PDF preview	Built-in Overleaf preview; SumatraPDF for desktop.
Backup	Daily zip download of the Overleaf project.