

Week 1 – Wednesday

Mathematical Modeling (Math 420/620)

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The Art of Mathematical Modeling

Reading: Ch 9 ([PDF](#)) from Ellner and Guckenheimer (2006)

<http://press.princeton.edu/titles/8124.html>

Read Up to 9.2.1 well, skim 9.2 - 9.6, Read 9.7-9.8 well.

The Five-Step Method (MMM)

Author M. M. Meerschaert (MMM) writes:

“The mathematical modeling approach to problem solving consists of five steps:

- ① Ask the question.
- ② Select the modeling approach.
- ③ Formulate the model.
- ④ Solve the model.
- ⑤ Answer the question.”

Ask the question – Step 1

- ① Questions exists in a *Real-world Context*
- ② (aka *Application Context*, *Scientific Context*, etc)
- ③ Often more than one question!
- ④ **This is a crucial step!** Questions guide everything.

Select the modeling approach – Step 2

- ① What assumptions are made about the real-world system?
- ② How do they translate into *mathematical* assumptions?
- ③ Can we simplify either set of assumptions?
- ④ Use the right tool for the job:

Let question(s) and these assumptions ultimately determine the modeling approach.

Formulate the model – Step 3

- ① Use assumptions about the system, and question(s), to guide model development.
- ② Translate *real-world* questions into mathematical or statistical questions that we can apply in our *model context*.
- ③ Do we need more than one model?

Solve Analyze the model – Step 4

- ① Highly dependent on your question and type(s) of model(s)!
- ② Analysis? Simulation? Approximation? etc.
- ③ **Goal: Obtain results that answer your question(s).**

Answer the question – Step 5

- ① How do your mathematical results address the original real-world question(s)?
- ② Take results from the context of your model(s), and discuss how they translate into the motivating 'real-world' context.

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Important observations (see Ch. 9 of Ellner and Guckenheimer, 2006):

- This is an iterative process! You won't get it right the first time.
- Start SIMPLE!
- *“Essentially, all models are wrong, but some are useful.”* – G.E.P. Box

The Three Commandments (For Modelers)

- ① **Lie** – Balance model simplicity with reality. Distill the system down into the simplest model necessary to answer your questions. Start VERY simple.
- ② **Cheat** – Don't ignore expert opinion, intuition. Use it to fill in information gaps, abuse statistical models, make handwaving approximations, etc. But, do so carefully!
- ③ **Steal** – Don't reinvent the wheel! Use existing information, tools, models, parameter values, etc. But, be critical and careful to avoid errors.

Disclaimer: More familiar forms of lying, cheating, and stealing should be avoided.



Example

Chapter 1 of MMM