L2: Jan. 24, 2017. 1

Housekeeping

- HW1 due today (now)
- HW2 due ~~Wednesda~~ Thursday in class (find it on Canvas later today)
- SPECIAL EVENT: TONIGHT!

  Hidden Figures movie at N. Adams movieplex

  - 6:40 p.m., 9:~~40~~ 20 p.m.
  - Line-up for free tickets (bring MCLA Student ID) starts at 6:00 p.m.
  - Non-(MCLA students): tickets $5.00

- Can everyone access course web site? Download module files?

Last time: Module 1.1 & beginning of 1.2. (QUESTIONS?)

Today:
- Finish 1.2
- Start 2.1?

Steps of the Modelling Process — p. 9

Note: this process is dynamic — can go back and revise the model at any point, if necessary!

1. Analyze the Problem.
   - What's the objective of the model? (As precisely as possible)
   - Deterministic or stochastic?
   - Static or dynamic?
   - If dynamic — discrete time or cts. time?

2. Formulate model (abstraction!)

   (a) Gather data
   - Inputs & outputs — pay att'n to units, how the data is collected & by whom, and to whether there may be observable intermediate steps. For checking model operation and for helping with the next steps...

   (b) Make & document simplifying assump'ns.
   - "Reality" is highly chaotic, complex, billions of variables. You want as few as necessary to achieve the objective (step 1).

(c) Determine variables & their units/dimensions.

- Independent variables (e.g., time)
- Dependent variables (e.g., temperature profile, etc.)
- Dimensions:
  - length
  - mass
  - time
  - charge
  - temperature
- Units:
  - meters, inches, lightyears, Angstroms
  - grams
  - seconds, years
  -
  - °F, °C, K
- Dimensional analysis — identifying fundamental quantities (Buckingham Π theorem — will learn)

(d) Establish relationships among variables & submodels.

- DRAW A DIAGRAM OF THE MODEL!
  - Helps you determine a file structure for writing routines & subroutines, or functions & sub-processes.

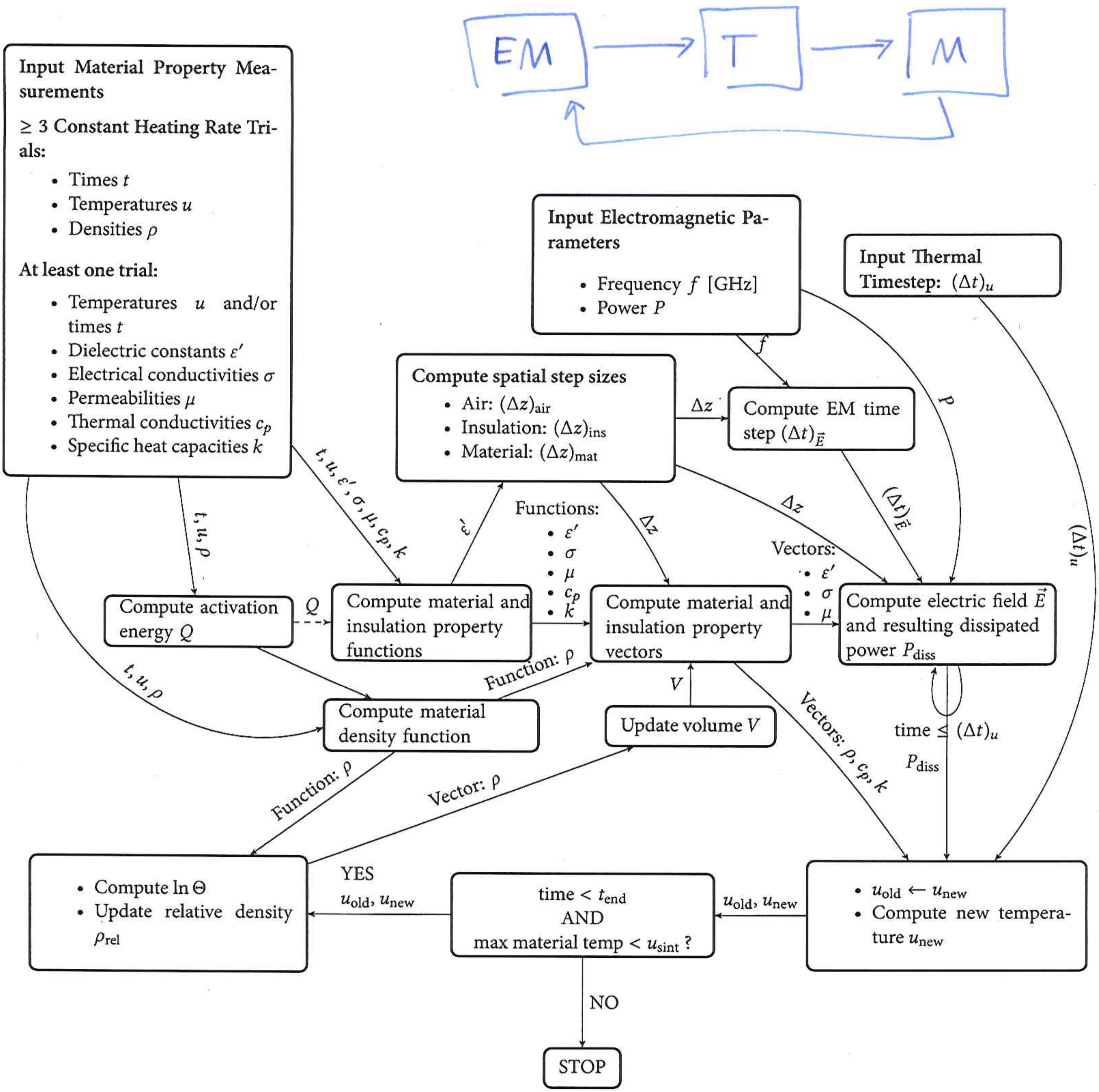

Figure 10.1: Flowchart showing operation of the coupled multiphysics, multiscale model of microwave sintering.

(e) Determine equations & functions.

- How did you know where to put the arrows in the diagram? — Eq'ns & fns. establish relationships btwn. quantities — how you move btwn. blocks of the diagram.

- Examples:
  - Solve a differential eq'n to get electric field from time, temperature, input power, material properties, etc.
  - Use a linear (?) relation btwn. quantities, if that's a faithful approximation (e.g., dissipated power ~ el. field magnitude)
  - Etc.! — This is where the math is!

3. Solve the model

- Write your code!
  - Computer packages (multiphysics solvers like COMSOL, Ansys, Abaqus, etc. — or specialty solvers like Sonnet (electric field solver), etc.)
  - Computer programs (your own code?)
  - Visualization — graphics?

4. Verify & interpret the model's sol'n

- Verification : solving the problem right
  (is the sol'n really a viable ...
  ... temp. profile? electric field?
  population value? etc.?)

- Validation : solving the right problem
  (is the result <u>what you expect</u>? —
  — compare to "actual" data)

- Pay attention to convergence, and realize the model's limitations — your mesh might not allow for complex geometries, or your time step size might restrict utility to a certain time interval — or, changing input data might necessitate a re-start of the simulation? ≸

- Does the sol'n suggest we can simplify anything? Does it suggest we ~~can~~ should <u>refine</u> anything?

  — Sensitivity analysis —

5. Report on the model

- To whom? - why are you doing this?

(a) Analysis of the problem

- Audience matters — clarity is key

(b) Model design

- Again, audience matters. Your collaborators + labmates get smth. very different than your customers, or your audience at a conference.

- Diagrams are useful!

(c) Model Sol'n

- Can leave some detail in appendices — again, depends on audience!

(d) Results & conclusions

- Pretty graphics? Tables? Figures - be fastidious!
- Axis labels, tick marks, tick labels, legends, titles, etc. — they ~~all~~ each have a purpose!

6. Maintain the Model.

- Host a web page? Write user manual? Debug?

Notes on model development:

- Keep detailed notes! — This helps greatly with a "final" report.

- Revisit items as necessary — a dynamic <u>process</u>!

- Unlike many math courses/problems, the goal is <u>not</u> to "get a (right) answer" — reality is very complex — but to get the answer(s) that best fit your original goal. Sometimes, this is quite open-ended! (e.g., "make a model that can be used for CAD & optimization" — optimization of <u>what</u>? What are the adjustable parameters? — sometimes requires several iterations of conversation with engineers/experimentalists).