Final Exam Project

ChEn 533 – Transport Phenomena

Overview

The transport project will serve as both the culminating learning experience in our class and as your final assessment for the course. For the project, you will pick a "classic paper" (or an equivalent problem) in chemical engineering transport phenomena and reproduce some or all of the results from the paper using the methods we have learned in class. You will be expected to present your method and results to the class in a short paper (approximately 4 pages, single spaced) and an oral report (15 minutes). I have provided some suggestions of papers that you may use, but you are also free to choose a paper that is tailored to your specific interests. Be creative and have fun but remember that your time is limited. Keep in mind that I am expecting you to present a completed project with a well-written report, so be careful to limit your scope and choose a problem that is within your capabilities given the time allotted.

The project deliverables consist of:

1. A 1-page project proposal due on **Fri., Apr. 3rd**.
2. A 4-page written report due by the time of the oral presentation on **Tue., Apr. 22nd**.
3. A 15-minute oral presentation to be given during our regularly scheduled final on **Tue., Apr. 22nd**.

The project grades will be based on the following:

1. Quality of the project including creativity, use of the methods we've learned in-class to solve PDEs, applicability of the project to transport phenomena, and degree of difficulty (30%)
2. Completion of work, understanding of the method, and quality and accuracy of results (40%)
3. Written and oral presentation (30%)

Note that 70% of the grade is based on the technical aspects of the project itself: its concept, the results obtained, completion of the project, answering the question posed, etc. Of course, my understanding of how well you were able to do the technical aspects will come from both the oral presentation and written report.

Last Updated: 03/24/26

Note about Academic Honesty

This project is more of an exam than a homework assignment. It is not a typical "take-home exam" in the sense that you are highly encouraged to use the internet, textbooks, the TA, and the instructor for help. However, it is meant to represent **your own effort**, not that of someone else. As such, you should not work together with your classmates on your project. Instead, the project should represent your own effort. This is obviously a gray area, so I expect you to use your best judgment. I don't anticipate any academic dishonesty, but if there is, I will use the "I know it when I see it" standard. Please do your best work!

Description of Deliverables

Project Proposal

The project proposal is meant to help you decide which paper/problem you are going to do, and to receive feedback and approval from me. The proposal should be **one page** long (single-spaced), and should answer the following questions:

1. *What is your project scope*? You need to (a) identify the problem you are going to solve and (b) describe the source(s) (e.g. paper, book, etc.) that you will use as your primary references. In addition, you need to (c) identify the methods that you will use to solve the problem.

2. *Why this problem?* You must (a) justify why this paper is important or interesting to you and to the wider scientific/chemical engineering community. You must also (b) justify why this problem is appropriate for a graduate-level transport phenomena course.

3. *How are you going to do this?* You should provide a brief plan/schedule for completing the project that includes sub-tasks, estimates of the time needed to complete these tasks, and dates for accomplishing the sub-tasks.

Project Proposal Rubric (30 pts)

Proposal Element	**Points**
What is your project scope? (a), (b), (c)	10
Why this problem? (a), (b)	5
How are you going to do this?	5
Formatting (1 page) and grammar	Penalties as needed
Approval to proceed	10

Written Report

The objective of your report is to teach us something new that you learned from studying this classic transport problem. As such, the audience for your report is the class. When writing, assume a level of expertise typical of your classmates.

The paper should be in the format of a technical/scientific publication (Introduction, Methods, Results/Discussion, and Conclusion). Use appropriate wording, grammar, formatting, and citations that are conventional for scientific writing. Focus on the question that you are addressing from the classic paper, the approach used, and the results you reproduced. For more tips about writing technical papers, you can check out my Github page on the topic.

The paper should be long enough to identify the problem, clearly convey the method used to solve the problem, and state the results with logical deductions as to how your work answers the question posed in the objective. You should not belabor things that we have already discussed in class, but you should instead focus on new methods or results that you have learned as part of the project. The focus of the paper is on what you did and the creative aspects for which you have used the simulation and any new methods you have used. The paper should be brief and succinct, but well-written. I am expecting no more than about four pages.

Specifically, the following sections should be included in the paper:

1. **Introduction:** Provide some background about the question that the authors of your paper are addressing. Put the paper in context. What physical situation are they trying to develop a model/theory for? Why is this important? What is the motivation? Are there any other methods for addressing this question? This section should typically be one page or less.

2. **Methods:** First, give us a brief overview of the methods used in the paper. What type of equations are they solving? What techniques are they using to solve them? Provide references to sources of these solution methods. These references could be our textbook, or another source you found. A random internet website is not an appropriate reference. Once you've done this, set up the problem and write up a detailed description of the solution. Be sure to describe any assumptions. The mathematical steps should be written in paragraph form, with the equations and algebra steps described as part of whole sentences. For an example, take a look at one of my recent papers where I did a lot of math. Because this derivation is a big part of the report, this section should probably be one to two pages in length. If you are having a hard time limiting your paper to 4 pages, you may provide an appendix with additional details of the derivation.

Your appendix will not count towards your page count, but it should be a supplementary document with details only.

3. **Results and Discussion:** In this section you should provide one or more figures that show the results of your analysis. Discuss what these figures show, and what the solution means. What physical insight do we gain from the solution? In addition, discuss the effects of any of your assumptions on the results. Depending on the number of figures, this section should be one or more pages in length.

4. **Conclusion:** In the concluding section, provide some context for the results you have shown. What impact did this paper have on the field of transport? What applications are related to the theory you derived? How have subsequent researchers used this theory? Make sure you resolve the questions you raised in the Introduction. In addition, discuss what you learned in doing the report. What new insights did you gain about transport phenomena, solving PDEs, etc.?

Oral Presentation

Oral presentations are scheduled during our final exam time in 15-minute slots. This allows 12 minutes for the presentation and 3 minutes for a question-and-answer period. Presentations will be made in our classroom during the time allotted by the University for our final exam. You are expected to attend all of the presentations by your classmates.

Your presentation should also follow the IMRAD format typical of scientific presentations. For more details about giving a good scientific presentation, you can look at the materials I have posted online for ChEn 391.

Like the written report, your audience for the presentation is the class, and your objective is to teach us something. I will be far more impressed (and therefore more likely to give a high score) to a student who teaches a concept clearly, rather than someone who tries to shower us with complicated details.

I also expect you to give a succinct and well-prepared presentation. You will likely be tempted to make too many slides, so I suggest that for a 12-minute presentation, you have no more than 12 slides. This is a suggestion based on years of giving presentations, not a strict requirement.

Final Report/Presentation Rubric (100 pts)

Proposal Element	**Points**
Project Quality	
(a) Project creativity and degree of difficulty	15

(b) Appropriate use of graduate-level methods	15
Project Completion	
(a) Complete scope of the project is achieved, and the solution/results are correct.	20
(b) Student demonstrates understanding of project	20
Project Communication	
(a) Oral Presentation	15
(b) Written Report	15

List of project ideas/classic papers

A note about these project ideas. Many of the papers I found have solutions that are also reproduced in textbooks or research monographs. I would highly recommend that you find a book problem related to the subject to help you narrow your scope. I really don't care if you have a "classic paper" per se, but rather that you have a good problem to solve. Also, you may not choose to do one of the example problems posted online as your project.

- **Pick one of the "D" homework problems from "Transport Phenomena" by Bird, Stewart and Lightfoot (BSL).**
- **Taylor-Dispersion**
  - Idea: Solve for the concentration profile in the large Peclet number, long time limit.
    - G. I. Taylor, Dispersion of soluble matter in solvent flowing slowly through a tube. Proc. R. Soc. London, Ser. A. 1953.
    - See also: Section 20.5 in BSL.
- **Surface Tension and Capillarity**
  - Idea: Solution/Stability analysis to the Marangoni Instability
    - C. V. Sternling and L. E. Scriven. Interfacial Turbulence: Hydrodynamic Instability and the Marangoni Effect. AICHE Journal. 1959.
- **Colloidal Science**
  - Idea: Calculate the mobility of a colloid undergoing electrophoresis.
    - J. L. Anderson. Colloid Transport by Interfacial Forces. Ann. Rev. Fluid Mech. 1989. 21: 61-99. 1989.

- **Electrokinetics**
  - Idea: Solve the Poisson-Boltzmann equation to find the distribution of an electrical double layer around a surface.
    - Grahame, D. C. "The Electrical Double Layer and the Theory of Electrocapillarity," Chemical Reviews, 41 (1947), 441-501.
    - See also: Ch. 15 in "Analysis of Transport Phenomena" (2^{nd} edition) by William Deen and "Electrochemical Systems, 3^{rd} Ed." by J. Newman.
    - Note: Reproducing Example 15.4-1 and 15.4-2 from Deen, Ch. 15 is not sufficient for this project. You must go beyond these examples in some way.
- **Classic Hydrodynamic Stability**
  - Idea: Solutions/stability analysis to the Orr-Sommerfeld equation.
    - W. M. Orr. The Stability or Instability of Steady Motions of a Perfect Liquid and of a Viscous Liquid Part II: A Viscous Liquid. Proceedings of the Royal Irish Academy. Section A: Mathematical and Physical Sciences. 1907
    - Orszag, S. A. "Accurate Solution of the Orr–Sommerfeld Stability Equation." J. Fluid Mech. 1971, 50 (4), 689–703. https://doi.org/10.1017/S0022112071002842.
  - Idea: Solutions/stability analysis for the Rayleigh-Taylor instability
  - Idea: Solutions/stability analysis for the Kelvin-Helmholtz instability
- **Boundary Layer Theory**
  - Idea: Calculate the separation point on a sphere using boundary layer theory
- **Kinetics of Phase Separation**
  - Idea: Calculate the preferred domain size of a liquid that phase separates by spinodal decomposition. This is a theory for the kinetics of a liquid-liquid phase separation.
    - Cahn, J. W. "Phase Separation by Spinodal Decomposition in Isotropic Systems." J. Chem. Phys. 1965, 42 (1), 93–99. https://doi.org/10.1063/1.1695731.
- **Lubrication problems**
  - Idea: Spin-coating a liquid.

    - Emslie, A. G.; Bonner, F. T.; Peck, L. G. "Flow of a Viscous Liquid on a Rotating Disk." J. Appl. Phys. 1958, 29 (5), 858–862. https://doi.org/10.1063/1.1723300.

- **Viscoelasticity/Rheology**
  - Idea: Determine the velocity profile of blood flowing in a cylindrical pipe.
    - Merrill, E. W. "Rheology of Blood." Physiol. Rev. 1969, 49 (4), 863–888. https://doi.org/10.1152/physrev.1969.49.4.863.
- **Turbulence**
  - Idea: Derive the "law of the wall" for a turbulent flow
    - Bradshaw, P.; Huang, G. P. "The Law of the Wall in Turbulent Flow." Proc. R. Soc. London, A 1995, 451 (1941), 165–188. https://doi.org/10.1098/rspa.1995.0122.
- **Combined Heat/Mass/Momentum Transfer**
  - Idea: Solution/Stability analysis for the Rayleigh-Bénard problem (free convection)
- **Combustion**
  - Idea: Model of the diffusion flame (e.g. a candle)
    - S. P. Burke and T. E. W. Schumann, "Diffusion Flames", Industrial and Engineering Chemistry, Vol 20, No 10, pp. 998–1004 (1928).
    - I. Glassman and R. A. Yetter. "Combustion", Fourth Edition, Elsevier 2008. Chapter 6. Diffusion Flames. (Some interesting projects may also come from Ch. 4 on premixed gases).