# CEGE 8211: Advanced Theory of Traffic Flow

Spring 2018

## 1 Instructor

Dr. Michael Levin
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**Office:** CivE 140
**Office hours:** M 3:00 PM – 4:00 PM; Th 1:30 PM – 2:30 PM or by appointment
**Course website:** Canvas

**Course meeting time and place:** T/Th 1:00 PM – 2:15 PM, CivE 214

## 2 Course description

This course is designed to prepare graduate students to understand and conduct research on traffic flow theory. The high-level objectives include:

- Developing a conceptual understanding of traffic flow, and how and where congestion forms.
- Translating the conceptual understanding into mathematical modeling.
- Large-scale implementation of numerical solution techniques.

This course will provide a rigorous mathematical coverage of traffic flow parameters and relationships, queueing models of traffic flow, kinematic wave theory and solution methods, mesoscopic node models, and optimal control. A strong emphasis is given to proving analytical properties and implementing traffic flow models in software. After completing this course, you should have a deep analytical understanding of the standard traffic flow models as well as the experience and skills to use and extend the state-of-the-art in your own models.

## 3 Course format

This course is taught using a modified Moore method. Class time is primarily spent working collaboratively to prove analytical properties of traffic flow theory, which is designed to advance your proof skills as well as their subject knowledge. Students are expected to complete proofs and defend their logic to other students in class. Assignments emphasize implementation of analytical concepts in software to facilitate dynamic network loading on city networks.

### 3.1 Prerequisites

The only official prerequisite for CEGE 8211 is graduate standing, but undergraduate students may enroll with instructor permission. Coursework will make use of multivariable calculus, differential equations, formal mathematical proofs, programming (in Java), and some optimization techniques. If you are not familiar with these topics, or it has been some time since you took the class, you will find it worthwhile to review them before the semester starts. Please speak to me if you have concerns about your preparation for the course.

### 3.2 Course materials

The only required text is *Transportation Network Analysis* by Stephen D. Boyles, Nicholas E. Lownes, and Avinash Unnikrishnan.

Another *recommended* textbook is *Traffic Flow Dynamics* by Martin Treiber and Arne Kesting. As an 8000-level course, many of the topics are both highly technical and are not covered in most textbooks. *Traffic Flow Dynamics* covers some of the key aspects of kinematic wave theory, and I recommend you acquire a copy. Lecture slides will also be posted on Canvas.

## 4 Assessment

Final course grades are determined by performance on the following items:

| Category | Weight |
|---|---|
| Homeworks | 35% |
| Exam | 25% |
| Project | 30% |
| In-class participation | 10% |

Please feel free to contact me at any time during the semester to discuss your progress to date. Requests for regrading must be submitted no more than one week after grades are posted.

### 4.1 Homeworks

Homeworks will be assigned throughout the semester, and will comprise a mix of conceptual, analytical, and computational questions. Large-scale computation is necessary for applying traffic flow theory in practice, and some of the homework problems will require you to implement traffic flow models in Java. I have created a Netbeans project containing a source code skeleton for traffic flow simulation in Java, which is available on the course website. If you are new to Java and/or object-oriented programming, you may find it helpful to review the Java tutorials linked here: `mwlevin.weebly.com/softwaredesign.html`. Email source codes and spreadsheets to me as part of the homework submission. (Zip up the entire

Netbeans project and email it to me. I will open your project on my computer to grade it). You will need to download and install the Java Development Kit and Netbeans IDE, both of which are free.

Homeworks comprise a major portion of the final grade, and will require significant time and effort. Do not wait until the night before to start! You are encouraged to work together on homeworks, but you must write your solutions separately, in your own words. Late homeworks are only accepted if you notify me of a time conflict or need for extension 24 hours *before* the due date.

## 4.2 Exam

The exam will take place before the end of the semester, and is comprehensive. No final exam is scheduled during finals week. This exam is open-book and open-notes. Internet- or communications-capable devices may not be used.

If you have a schedule conflict with the exam, please inform me as far in advance as possible so that alternative arrangements can be made. Depending on the circumstances, these arrangements may include taking a different exam before or after the scheduled time, additional assignments, and/or adjusting a student's final grade distribution. Except for unforeseen and documented emergencies, makeup exams will not be given without prior notice.

## 4.3 Project

A major component of the grade is completing a course research project. Potential project topics include application of one or more traffic flow models to a real-world scenario, presenting one or more important journal papers (please discuss with me beforehand), comparison of different traffic flow models or algorithms for the same problem, development of a computer tool to solve a traffic flow model, or another related topic of interest.

You must work individually on projects. **Please send your project topic to me for approval no later than March 19**, but you are strongly encouraged to start earlier. At the end of the semester, you will be required to present your project to the rest of the class, and document all of your work in a **written report due on May 7**.

## 4.4 In-class participation

In-class activities will consist of solving problems or proving theorems posed to the class. After solutions have been found, individual students will be asked to volunteer to defend their solutions or proofs in front of the class. The participation score is based on how much you present solutions to the class.

## 5 Schedule

A tentative class schedule is shown below, but dates and topics are subject to change.

| MONDAY | | WEDNESDAY | |
|---|---|---|---|
| 1/20<br>*MLK Day* | | 1/22<br>Orientation | **1** |
| 1/27<br>Review of object-oriented programming | **2** | 1/29<br>Exit functions and point queues | **3** |
| 2/3<br>Point queues and spatial queues | **4** | 2/5<br>Merge/diverge node models | **5** |
| 2/10<br>Kinematic wave theory | **6** | 2/12<br>Kinematic wave theory | **7** |
| 2/17<br>Kinematic wave theory | **8** | 2/19<br>Cell transmission model | **9** |
| 2/24<br>Cell transmission model | **10** | 2/26<br>Dynamic traffic assignment | **11** |
| 3/2<br>Dynamic traffic assignment | **12** | 3/4<br>Newell's method | **13** |
| 3/9<br>*Spring break* | | 3/11<br>*Spring break* | |
| 3/16<br>Paper presentations | **14** | 3/18<br>Link transmission model | **15** |
| 3/23<br>Link transmission model | **16** | 3/25<br>Hamilton-Jacobi equations | **17** |
| 3/30<br>Lax-Hopf method | **18** | 4/1<br>Lax-Hopf method | **19** |
| 4/6<br>General node models: properties | **20** | 4/8<br>Traffic signals | **21** |
| 4/13<br>**Semester exam** | **22** | 4/15<br>Dynamic programming / optimal control | **23** |
| 4/20<br>Max-pressure intersection control | **24** | 4/22<br>Max-pressure intersection control | **25** |
| 4/27<br>Max-pressure intersection control | **26** | 4/29<br>Project presentations | **27** |

# 6 Miscellania

The University of Minnesota provides, upon request, appropriate academic adjustments for qualified students with disabilities. For more information, contact the Disability Resource Center at https://diversity.umn.edu/disability/.

Students who violate University rules on scholastic dishonesty are subject to disciplinary penalties, including failing the course and/or dismissal from the University. Since dishonesty harms the individual as well as other students, policies on scholastic dishonesty will be strictly enforced. If you are unsure of whether an action constitutes scholastic dishonesty, please contact me first. For further information, see https://cse.umn.edu/r/scholastic-integrity/.