**CE 376: Transportation System Operations**
**Fall 2024**

**Course:**

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| Time: | MW 8:00 - 9:50 am |
| Room: | Technological Institute L168 |
| Final exam: | 7-9 PM, 12/11/2024 |

**Instructor:**


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**Description:** The purpose of this course is to introduce students to the principles of transportation engineering with a focus on highway engineering and traffic analysis. The course covers fundamental concepts and principles that guide road design, as well as the movement and control of vehicular traffic. Specifically, these include geometric design, traffic flow theory, highway capacity analysis, and traffic signal operations.

The materials learned are intended to provide the basic skill set that will allow students to solve transportation problems that are likely to appear in professional practice and on the Fundamentals of Engineering exam (FE) and the Principles and Practice of Engineering exam (PE). The materials also serve as a foundation for future coursework in transportation.

The course is designed for upper level undergraduate students and entry-level graduate students.

**Prerequisites:** Basic undergraduate calculus and statistics courses.

**Course requirement:**

- Eight problem-oriented assignments. The objective of these assignments is to assist in the learning of course material, so discussion of assignments among students is encouraged.
- One mid-term and one final exam will be given. Both exams will be closed-book but the student is allowed to bring one 8-1/2 by 11 inch "cheat sheet" to the exam.

**Grading:** The final grade will be assigned on the following basis:

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| Homework | 30% |
| Mid term exam | 30% |
| Final exam | 35% |
| Participation | 5% (Students are expected to actively participate in class discussions) |

**Text:** The required text is "Principles of Highway and Traffic Engineering" Fifth Edition, by Fred L. Mannering, Scott S. Washburn, and Walter P. Kilareski, John Wiley & Sons, 2011. Available at bookstores, amazon.com, bn.com, and other sources. The textbook will be supplemented by class notes.

**References:**
Nicholas J. Garber and Lester A. Hoel. (2002) Traffic and Highway Engineering, Third Edition, PWS Publishing Company.
James H. Banks. (2002) Introduction to Transportation Engineering, Second Edition, McGraw-Hill.

**Other requirements**

- Generative AI: You are required to disclose how you have used generative AI to complete your homework. Depending on the extent of its use, your grade may be impacted. For instance, if you simply provide the question to AI and copy its response without additional effort, you may not receive any credit. Failure to report your use of AI may be considered academic misconduct. Additionally, using AI during exams is strictly considered cheating.
- Late submission: Students are expected to submit their homework and project reports in time. The base grade of late homework will be depreciated 10% for every 24-hour delay (up to 30%), unless it is the result of an officially excused absence.
- Working together: Working together on homework is encouraged, although students are expected to write up their own versions of solutions. Working together on exams is forbidden.
- Calculator: Students may use a graphic calculator on exams and homework. Students may not use laptop computers and/or any machine with symbolic manipulation capabilities on exams.

## Subject area and learning objectives

**Introduction**

- *Topics*: Transportation and society; challenges arising from transportation systems; basic components of highway systems.
- *Learning objectives*: to understand basics and fundamental challenges in transportation systems, particularly highway systems.

**Basic vehicle dynamics**

- *Topics*: Space-time diagram; vehicle movement analysis based on constant accleration/deceleration; stopping distance; safe following distance; vehicle performance (resistance, acceleration, deceleration, braking)
- *Learning objectives*: to understand fundamental physical rules that govern vehicle movement and influence vehicle performance; to be able to apply these rules to solve simple traffic and road design problems.

**Geometric design of highways**

- *Topics*: Sight requirements; superelevations; horizontal and vertical alignments.
- *Learning objectives:* to be familiarized with the elements involved in geometric design and the safety concerns that motivate vertical and horizontal curve design; to be able to perform a rudimentary geometric design of a highway section.

**Elements of traffic flow theory**

- *Topics*: Definition and measurement of traffic quantities; relationship between traffic quantities; time-mean vs. space-speed; inductive loops; identify and measure traffic congestion.

- *Learning objectives*: to be familiarized with basic quantities that describe vehicular traffic; to build a foundation for understanding highway capacity, as well as more advanced traffic flow theory that explains the mechanism of traffic congestion.

**Traffic control at signalized intersections**

- *Topics*: Signal control hierarchy and warrants; signal timing design methods.
- *Learning objectives*: to be familiarized with the elements of signal operations and signal timing analysis methods; to be able to use both analytical methods and commercial software (Synchro) to solve simple signal design problems.

**Car-following behavior and traffic stream models**

- *Topics*: California Motor Code Rule; General-Motor car-following models.

- *Learning objectives*: to understand the relationship between car-following behavior and the macroscopic properties of traffic stream; to be able to derive various speed-density and flow-density models from corresponding car-following models.

**Queueing theory**

- *Topics*: Deterministic first-in-first-out queuing theory; bottleneck traffic model; stochastic queuing theory (M/M/1, M/D/1)
- *Learning objectives*: to be familiarized with fundamental principles in queuing analysis; to be able to apply simple deterministic and stochastic queueing models to analyze various traffic phenomenon; to develop a foundation for understanding more complex queuing systems.

**Highway capacity analysis**

- *Topics*: Basic freeway segments; multi-lane highways.
- *Learning objectives*: to understand the basic highway capacity analysis methods; to be able to use these methods to conduct simple LOS (level of service) analysis for freeway and multi-lane highways; to develop a basis for understanding Highway Capacity Manual (HCM) and the HCM-based commercial design software.

**Kinematic wave theory**

- *Topics:* Conservation law; LWR model and its basic solution; acceleration, deceleration and shock waves.
- *Learning objectives*: to understand the concept of kinematic wave (KW) theory and its application in traffic analysis; to be able to use the KW theory to analyze the formation and propagation of traffic congestion in simple cases; to develop a basis for understanding advanced traffic analytical tools including traffic simulation.

**ABET Program Educational Objectives**

For students completing undergraduate degree programs in civil engineering or in environmental engineering, this course addresses the following Program Outcomes [1]:

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. (H,E) [2]

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. (H,E)

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts. (H,E)

[1] These outcomes correspond to the "1-7" Learning Outcomes specified by the Accreditation Board of Engineering and Technology (ABET)

[2] Homework (H), Exams (E), and Written Reports (R) refer to the deliverables that are used to meet the learning outcomes.

Table 1: Tentative schedule: Fall 2024

| Date | Week | Topic | Text | Assignment | Due |
|---|---|---|---|---|---|
| 23-Sep-24 | 1-1 | | | | |
| 25-Sep-24 | 1-2 | Introduction | Chapter 1 + notes | | |
| 30-Sep-24 | 2-1 | Basic vehicle dynamics | Chapter 2 + notes | HW1 | |
| 2-Oct-24 | 2-2 | Basic vehicle dynamics | Chapter 2 + notes | | |
| 7-Oct-24 | 3-1 | Geometric design | Chapter 3 | | |
| 9-Oct-24 | 3-2 | Geometric design | Chapter 3 | HW2 | HW1 |
| 14-Oct-24 | 4-1 | Elements of Traffic Flow Theory | Chapter 5+ notes | | |
| 16-Oct-24 | 4-2 | Elements of Traffic Flow (online or asynchronous) | Chapter 5+ notes | HW3 | HW2 |
| 21-Oct-24 | 5-1 | Car-following behavior and traffic stream | notes | | |
| 23-Oct-24 | 5-2 | Car-following behavior and traffic stream | notes | HW4 | HW3 |
| 28-Oct-24 | 6-1 | Queuing theory | Chapter 5 + notes | | |
| 30-Oct-24 | 6-2 | Queuing theory | | HW5 | HW4 |
| 4-Nov-24 | 7-1 | Midterm (tentative) | | | |
| 6-Nov-24 | 7-2 | Highway capacity analysis | Chapter 6 | HW 6 | HW5 |
| 11-Nov-24 | 8-1 | Highway capacity analysis | Chapter 6 | | |
| 13-Nov-24 | 8-2 | Traffic control | Chapter 7+notes | | |
| 18-Nov-24 | 9-1 | Traffic control | Chapter 7+notes | HW7 | HW6 |
| 20-Nov-24 | 9-2 | Traffic control | Chapter 7+notes | | |
| 25-Nov-24 | 10-1 | Kinematic wave theory | | HW8 | HW-7 |
| 27-Nov-24 | 10-2 | Thanksgiving (class cancelled) | | | |
| 2-Dec-24 | 11-1 | Kinematic wave theory | Notes | | |
| 4-Dec-24 | 11-2 | Review | | | HW8 |
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| 11-Dec-24 | | Final exam (7-9 PM) | | | |