IMPORTANT:
Please refer to the USC Center for Excellence in Teaching for current best practices in syllabus and course design. This document is intended to be a customizable template that primarily includes the technical elements required for the the purpose of central review by UCOC.

ISE 632: Network Flows and Combinatorial Optimization

Units: 4

Spring 2024, Monday/Wednesday 2:00-3:50,

IMPORTANT:
The general expectation for a standard format course offered in a standard 15-week term is that the number of 50-minute contact hours per week should equal the number of semester units indicated and that one semester unit entails 1 hour of class time and 2 hours of outside work (3 hours total) per week. Standard fall and spring sessions (001) require a final summative experience during the University scheduled final exam day and time.

Please refer to the *Contact Hours Reference* to see guidelines for courses that do not follow a standard format and/or a standard term.

Location: KAP 145

Instructor: John Gunnar Carlsson
Office: OHE 310F
Office Hours: Tuesday 2:00-3:00
Contact Info: jcarlsso@usc.edu

Teaching Assistant: TBA
Office: Physical or virtual address
Office Hours:
Contact Info: Email, phone number (office, cell), Skype, etc.

IT Help: Group to contact for technological services, if applicable.
Hours of Service:
Contact Info: Email, phone number (office, cell), Skype, etc.

Course Description

- Graph theory: definitions, applications, handshaking lemma
- Matching problems: bipartite/non-bipartite, perfect, minimum weight matching, LP relaxations and their duals
- Total unimodularity: definition, applications, total dual integrality
- Network flow problems: max flow-min cut theorem, minimum cost flows, multi-commodity flows, minimum k -cut, multiway cut, non-linear flow problems
- Spanning trees: minimum spanning trees, Steiner trees, enumerating trees (Cayley's theorem/Matrix-tree theorem), arborescences, Gomory-Hu trees
- Routing problems: travelling salesman problems (TSPs), vehicle routing problems, generalized TSPs
- Location problems: k -medians, k -means, k -centers, k -dispersion
- Game theory on networks: selfish routing, location games, connection games, price of anarchy/stability
- Probability theory of combinatorial optimization problems: randomized algorithms, Beardwood-Halton-Hammersley theorem, random LPs

Learning Objectives

Students will learn and master strategies for modelling, solving, and analyzing optimization problems that arise in large and complex networks. These include location problems ("where should you put things"), routing problems ("how should things move from one place to another"), network design problems ("how should you connect things together"), and matching problems ("how should you pair things to other things").

Prerequisite(s): ISE 630 or similar graduate-level linear programming
Concurrent Enrollment: none
Recommended Preparation: linear programming, especially modelling and duality

Course Notes

Letter grades. All course content available via PDF slides on blackboard, with optional supplementary reading.

Technological Proficiency and Hardware/Software Required

N/A

Required Readings and Supplementary Materials

The following textbooks are all optional and accessible for free, and are merely for supplementing course content at your prerogative:

- Ravindra K. Ahuja, Thomas L. Magnanti, and James B. Orlin. Network flows: theory, algorithms, and applications. Prentice Hall, 1993. Available online at https://dspace.mit.edu/bitstream/handle/1721.1/49424/networkflows00ahuj.pdf
- Bernhard Korte and Jens Vygen. Combinatorial optimization: theory and algorithms. Springer, 2008. Available online via USC Libraries.
- David Easley and Jon Kleinberg. Networks, crowds, and markets: Reasoning about a highly connected world. Cambridge University Press, 2010. Available online at http://www.cs.cornell.edu/home/kleinber/networks-book/networks-book.pdf
- Adam Kasperski. Discrete optimization and network flows. Wrocław University of Technology, 2011. Available online at http://www.ioz.pwr.wroc.pl/pracownicy/kasperski/prv/discropt.pdf.

Description and Assessment of Assignments

Grading will be based on about 12 problem sets, a midterm exam, and a final exam. Students may collaborate in groups of two or three on homework, but each student must write up their own assignments.

Grading Breakdown

Including the above detailed assignments, how will students be graded overall? Participation should not exceed 15% of the total grade. Where it does, the syllabus must provide an added explanation. No portion of the grade may be awarded for class attendance but non-attendance can be the basis for lowering the grade, when clearly stated on the syllabus. The sum of percentages must total 100%.

Assessment Tool (assignments)	**Points**	**% of Grade**
Problem sets		40
Midterm exam		30
Final exam		30
TOTAL		100

Assignment Submission Policy

Assignments must be submitted either at the beginning of class or via blackboard.

Grading Timeline

All assignments will be returned with two weeks of submission.

Course Schedule: A Weekly Breakdown

Provide a detailed course calendar that includes a list of deliverables (homework assignments, examinations, etc.) broken down on a weekly basis. The format may vary, but the content must include:

- Subject matter (topic) or activity
- Required preparatory reading or tasks (e.g., viewing videos)
- Deliverables and when each deliverable is due. A blanket statement that there will be a deliverable due at a specified frequency (e.g., there will be homework due weekly) may obviate the need to state when certain deliverables are due

<u>IMPORTANT:</u>
In addition to in-class contact hours, all courses must also meet a minimum standard for out-of-class time, which accounts for time students spend on homework, readings, writing and other academic activities. Standard fall and spring sessions (001) require a final summative experience during the University scheduled final exam day and time.

	Topics/Daily Activities	**Readings/Preparation**	**Deliverables**
Week 1	Graph theory: definitions and applications	Lecture 1 slides	None
Week 2	Matching problems	Lecture 2 slides	PS1
Week 3	Total unimodularity	Lecture 3 slides	PS2
Week 4	Network flow problems, part 1	Lecture 4 slides	PS3
Week 5	Network flow problems, part 2	Lecture 5 slides	*PS4*
Week 6	Midterm 1 prep and exam	Practice midterm problems	Midterm 1
Week 7	Spanning trees, part 1	Lecture 6 slides	PS5
Week 8	Spanning trees, part 2	Lecture 7 slides	PS6
Week 9	Routing problems, part 1	Lecture 8 slides	PS7
Week 10	Routing problems, part 2	Lecture 9 slides	PS8
Week 11	Location problems	Lecture 10 slides	PS9
Week 12	Game theory on networks	Lecture 11 slides	PS10
Week 13	Probability theory of network optimization problems, part 1	Lecture 12 slides	PS11
Week 14	Probability theory of network optimization problems, part 2	Lecture 13 slides	PS12
Week 15	Final exam prep	Practice final exam problems	None

FINAL			Refer to the final exam schedule in the USC *Schedule of Classes* at classes.usc.edu.

Statement on Academic Conduct and Support Systems

[Paste most recent version of the statement here; see the CCO Resources page.]