Annexe A: New/Revised Course Content in OBTL+ Format

Course Overview

Expected Implementation in Academic Year	AY2022-2023
Semester/Trimester/Others (specify approx. Start/End date)	Semester 1
Course Author * Faculty proposing/revising the course	Gary Greaves
Course Author Email	gary@ntu.edu.sg
Course Title	GRAPH THEORY
Course Code	MH3300
Academic Units	4
Contact Hours	51
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	{MH1201 and MH1301} OR {MH2802}
Co-requisites	
Pre-requisite to	
Mutually exclusive to	
Replacement course to	
Remarks (if any)	

Course Aims

This course serves as an introduction to graph theory. As well as establishing some of the fundamentals of graph theory, this course aims to exhibit the wide range of applications enjoyed by graphs. The fundamentals of graph theory will be covered in a rigorous manner and you will be introduced to various graph invariants. You will see how these graphs invariants can be use to solve real-world problems. In particular, you will learn how to use graphs to solve scheduling problems, discrete optimization problems, and assignment problems.

Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

ILO 1	Determine whether or not two graphs are isomorphic
ILO 2	Count the number of certain walks, paths, and cycle in a graph
ILO 3	Identify smallest vertex and edge cuts
ILO 4	Count the number of spanning trees in a graph
ILO 5	Apply the augmenting path algorithm to find a maximal matching
ILO 6	Use eigenvectors of the Laplacian matrix to draw a graph
ILO 7	Find minimum vertex covers
ILO 8	Apply the Kuhn-Munkres algorithm to find a largest weight diagonal of a matrix
ILO 9	Find the chromatic number and chromatic polynomial of a graph
ILO 10	Find the maximum flow in a network
ILO 11	Find a minimum cut in a network
ILO 12	Apply techniques from the course to solve real-world problems

Course Content

Cayley's formula and the matrix-tree theorem
The Laplacian matrix and graph orientations
Berge's lemma, Konig's theorem, and Hall's marriage theorem
Brook's theorem
The Ford-Fulkerson algorithm and the max-flow min-cut theorem
Menger's theorem

Reading and References (if applicable)

J. A. Bondy and U. S. R. Murty GRAPH THEORY WITH APPLICATIONS, ISBN-13: 978-0444194510
D. B. West INTRODUCTION TO GRAPH THEORY, ISBN-13: 978-0130144003

Planned Schedule

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
1	Basic notions of graphs: Graphs, subgraphs, graph isomorphism, adjacency and incidence matrices, walks, paths, and cycles.	1,2,12	Lecture notes/tutorial problems	In-person	
2	Basic notions of graphs: Graphs, subgraphs, graph isomorphism, adjacency and incidence matrices, walks, paths, and cycles.	1,2,12	Lecture notes/tutorial problems	In-person	
3	Trees, cuts, and connectivity: Classifications of trees, cut-vertices, cut-edges, spanning trees, recursive counting, Cayley's formula, vertex cuts and connectivity, edge cuts and edge-connectivity.	3,4,12	Lecture notes/tutorial problems	In-person	

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
4	Trees, cuts, and connectivity: Classifications of trees, cut-vertices, cut-edges, spanning trees, recursive counting, Cayley's formula, vertex cuts and connectivity, edge cuts and edge-connectivity.	3,4,12	Lecture notes/tutorial problems	In-person	
5	The Laplacian matrix: The Laplacian matrix, orientations, signed incidence matrices, finding edge cuts, counting connected components, the matrix-tree theorem, how to draw a graph.	4,6	Lecture notes/tutorial problems	In-person	

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
6	The Laplacian matrix: The Laplacian matrix, orientations, signed incidence matrices, finding edge cuts, counting connected components, the matrix-tree theorem, how to draw a graph.	4,6	Lecture notes/tutorial problems	In-person	
7	Midterm 1 Matchings: Motivating problems, matchings, alternating paths, augmenting paths, Berge's lemma, the augmenting path algorithm, vertex coverings, Konig's theorem, Hall's Marriage theorem, weighted matchings, the Kuhn-Munkres algorithm.	6,7,8,12	Lecture notes/tutorial problems	In-person	

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
8	Matchings: Motivating problems, matchings, alternating paths, augmenting paths, Berge's lemma, the augmenting path algorithm, vertex coverings, Konig's theorem, Hall's Marriage theorem, weighted matchings, the Kuhn-Munkres algorithm.	5,7,8,12	Lecture notes/tutorial problems	In-person	
9	Graph colouring: Motivating problems, k-colouring, the chromatic number, bipartite graph classification, subgraph inheritance, excluding subgraphs, greedy algorithm for colouring, Brook's theorem, chromatic polynomials	9,12	Lecture notes/tutorial problems	In-person	

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
10	Graph colouring: Motivating problems, k-colouring, the chromatic number, bipartite graph classification, subgraph inheritance, excluding subgraphs, greedy algorithm for colouring, Brook's theorem, chromatic polynomials	9,12	Lecture notes/tutorial problems	In-person	
11	Midterm 2 Network Flow: Motivating problems, directed graphs, networks, capacity functions, flows, Ford-Fulkerson algorithm, Max-flow problem, Min-cut problem, Max-flow min-cut theorem, Menger's theorem.	10,11,12	Lecture notes/tutorial problems	In-person	

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
12	Network Flow: Motivating problems, directed graphs, networks, capacity functions, flows, Ford-Fulkerson algorithm, Max-flow problem, Min-cut problem, Max-flow min-cut theorem, Menger's theorem.	10, 11, 12	Lecture notes/tutorial problems	In-person	
13	Revision and Review	1, 2, 3, 4, 5, 7, 9, 10, 11, 12	Lecture notes/tutorial problems	In-person	

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Lectures	Derivations and proofs: Explanations of concepts and proof ideas will help you digest the course content. Examples: Many concrete examples will be provided in the lectures to help you understand abstract ideas.
Tutorials	Tutorials provide an environment where it is OK to make mistakes and ask for extra help. Tutorials will help you obtain clarification for concepts that are troubling or confusing.

Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
1	Continuous Assessment (CA): Others(Short Answer Questions)	1, 2, 3, 4, 5, 12	1. a, b, c, d 2. b, c, d 3. a	25		Individual	Analytic	Not Applicable
2	Continuous Assessment (CA): Others(Short Answer Questions)	6, 7, 8, 9, 12	1. a, b, c, d 2. b, c, d 3. a	25		Individual	Analytic	Multistructural
3	Summative Assessment (EXAM): Others(Short Answer Questions)	1, 2, 3, 4, 5, 6, 7,8, 9, 10, 11, 12	1. a, b, c, d 2. b, c, d 3. a	50		Individual	Analytic	Multistructural

Description of Assessment Components (if applicable)

These are the relevant SPMS-MAS Graduate Attributes.
1. Competence
a. Independently process and interpret mathematical theories and methodologies, and apply them to solve problems
b. Formulate mathematical statements precisely using rigorous mathematical language
c. Discover patterns by abstraction from examples
d. Use computer technology to solve problems, and to communicate mathematical ideas
2. Creativity
b. Build on the connection between subfields of mathematics to tackle new problems
c. Develop new applications of existing techniques
d. Critically analyse data from a multitude of sources
3. Communication
a. Present mathematics ideas logically and coherently at the appropriate level for the intended audience

Formative Feedback

Midterm Test: formative feedback is written in your midterm script, which will be handed back to you. Feedback on common mistakes midterm test scripts will be given in a feedback lecture.
You will also receive formative feedback for all learning outcomes in the Examiner's report (available on ntuLearn are the exam period).

NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

Attributes/Competency	Level
Collaboration	Basic
Creative Thinking	Advanced
Problem Solving	Advanced

Course Policy

Policy (Academic Integrity)

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values. As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Policy (General)

You are expected to complete all assigned class readings and activities, attend classes punctually and take all scheduled assignments and tests by due dates. You are expected to take responsibility to follow up with course notes and assignments, and to participate in tutorial discussions and activities.

Policy (Absenteeism)

Absence from class without a valid reason will affect your overall course grade. Valid reasons include falling sick supported by a medical certificate and participation in NTU's approved activities supported by an excuse letter from the relevant bodies.

If you miss a lecture, you must inform the course instructor via email prior to the start of the class.

Absence Due to Medical or Other Reasons

If you are sick and not able to attend a quiz or midterm, you have to submit the original Medical Certificate (or another relevant document) to the administration to obtain official leave. In this case, the missed assessment component will not be counted towards the final grade.

Policy (Others, if applicable)

Diversity and inclusion policy

Integrating a diverse set of experiences is important for a more comprehensive understanding of science.

It is our goal to create an inclusive and collaborative learning environment that supports a diversity of perspectives and learning experiences, and that honours your identities; including ethnicity, gender, socioeconomic status, sexual orientation, religion or ability.

To help accomplish this:

- If you are neuroatypical or neurodiverse, have dyslexia or ADHD (for example), or have a social anxiety disorder or social phobia;
- If you feel like your performance in the class is being impacted by your experiences outside of class;
- If something was said in class (by anyone, including the instructor) that made you feel uncomfortable;

Please speak to your teaching team, our school pastoral officer or a peer or senior (either in-person or via email) about how we can help facilitate your learning experience.

As a participant in course discussions, you should also strive to honour the diversity of your classmates. You can do this by: using preferred pronouns and names; being respectful of others opinions and actively making sure all voices are being heard; and refraining from the use of derogatory or demeaning speech or actions.

All members of the class are expected to adhere to the NTU anti-harassment policy. if you witness something that goes against this or have any other concerns, please speak to your instructors or a faculty member.

Appendix 1: Assessment Rubrics

Rubric for Mid-semester Quiz: Short Answer Questions (25%)

Point-based marking (not rubrics based)

Rubric for Mid-semester Quiz: Short Answer Questions 1 (25%)

Point-based marking (not rubrics based)

Rubric for Examination: Short Answer Questions (50%)

Point-based marking (not rubrics based)