NANYANG TECHNOLOGICAL UNIVERSITY

Teaching, Learning and Pedagogy Division

Reg. No. 200604393R

PROPOSED COURSE OUTLINE TEMPLATE FOR STUDENTS AT NTU

Academic Year	2017/2018	**Semester**	2
Course Coordinator	Kiah Han Mao		
Course Code	MH4300		
Course Title	Combinatorics		
Pre-requisites	MH1101 - Calculus II MH1201 - Linear Algebra II MH1301 - Discrete Mathematics		
No of AUs	4		
Contact Hours	4 hours per week (3 hours of lecture, 1 hour of tutorial)		
Proposal Date	07-Dec-2017		

Course Aims

This final year mathematics course aims to equip you to ***apply concepts in symbolic methods and analysis to solve a variety of problems in combinatorics***. The tools developed in the course are useful for future ***graduate courses in mathematics, applied mathematics and engineering***.

Intended Learning Outcomes (ILO)

By the end of this course, you (as a student) would be able to:

1. Define a generating function and describe its role in enumerating combinatorial structures.
2. Distinguish between ordinary, exponential and multivariate generating functions.
3. Apply the symbolic enumeration method to compute combinatorial configurations such as integer compositions, partitions, words, and tree structures (the list is not exhaustive).
4. Apply a variety of complex-analytic methods to extract asymptotic information from generating functions.

Course Content

- **Combinatorial Structures and Ordinary Generating Functions**: symbolic enumeration methods, integer compositions and partitions, words and regular languages, tree structures
- **Labelled Structures and Exponential Generating Functions**: labelled classes, surjections, set partitions, words, alignments, permutations, labelled trees, mapping and graphs
- **Complex Analysis, Rational and Meromorphic Asymptotics**: generating functions as analytic objects, analytic functions and meromorphic functions, singularities and exponential growth of coefficients
- **Singularity Analysis of Generating Functions**: coefficient asymptotics, process of singularity analysis

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team/Individual	Assessment rubrics
1. Final Examination	1, 2, 3, 4	MAS PLO A1, A2, A3, B1, B4	50%	Individual	Point-based marking
2. CA1: Assignment	1, 2, 3, 4	MAS PLO A1, A2, A3, A4, B1, B3, B4, E	25%	Individual	Point-based marking
3. CA2: Midterms	1, 2, 3	MAS PLO A1, A2, A3, B1, B4	25%	Individual	Point-based marking
Total			100%		

Formative feedback

CA1: Feedback is given after each individual assignment is returned. Students are allowed to resubmit for higher grades.

CA2: Feedback is given after the midterm on the common mistakes and the level of difficulty.

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Derivation and demonstration (Lecture & Tutorial)	Explains the motivation behind the symbolic enumeration method. Presents systematic ways to solve problems related to the concepts developed. Derives generating functions and use them to obtain asymptotic estimates.
Problem solving (Lecture & Tutorial)	Develops competence in solving a variety of problems related to combinatorics.
Peer Instruction (Tutorial)	Develops communication and presentation skills and deepen understanding. You will have the opportunity to work with peers and present your solution to the class.

Reading and References

P. Flajolet, R. Sedgewick, *Analytic Combinatorics*, Cambridge University Press, 2006 (978-0521898065 / 0521898064)

Course Policies and Student Responsibilities

You are encouraged to collaborate on the assignments because peer-to-peer learning helps you understand the subject better and working in a team trains you to better

communicate with others. As part of academic integrity, crediting others for their contribution to your work promotes ethical practice.
You have to submit **individual** assignments, and hence, do take note of this collaboration policy:

- You have to **write up every solution by yourself**, even if you collaborated with others to solve the problem.
- You are to explicitly identify your collaborators in the assignment. If you did not work with anyone, you should write "Collaborators: none". If you obtained a solution through research (e.g., on the web), you must acknowledge the source, but write up the solution in your own words. If no collaboration statement is made at all, you will receive a warning. In case this happens repeatedly, a penalty will be applied.
- It is a violation of this policy to submit a problem solution that you cannot orally explain.
- It is a violation of the collaboration policy for you to permit anyone other than the lecturers and tutors to see your written solutions. Ideas may be shared, but do not share your written solutions with other students.
- If you have any questions about the collaboration policy, or if you feel that you may have violated the policy, please talk to one of the lecturers.

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. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Kiah Han Mao	SPMS-MAS-05-39	--	hmkiah@ntu.edu.sg

Planned Weekly Schedule

*Section numberings are from P. Flajolet, R. Sedgewick, *Analytic Combinatorics*.

Wk	Topic	Course LO	Readings/ Activities
1	Symbolic enumeration methods Admissible constructions and specifications	1, 3	Section A.I.1 Section A.I.2
2	Integer compositions and partitions Words and regular languages	1, 3	Section A.I.3 Section A.I.4

	Tree structures		Section A.I.5
3	Labelled classes Admissible labelled constructions	1, 2, 3	Section A.II.1 Section A.II.2
4	Surjections, set partitions, and words Alignments, permutations, and related structures Labelled trees, mappings, and graphs	1, 3	Section A.II.3 Section A.II.4 Section A.II.5
5	An introduction to bivariate generating functions (BGFs) Bivariate generating functions and probability distributions	1, 2, 3	Sect A.III.1 Sect A.III.2
6	Inherited parameters and ordinary MGFs Inherited parameters and exponential MGFs Recursive parameters Complete generating functions and discrete models	1, 2, 3	Sect A.III.3 Sect A.III.4 Sect A.III.5 Sect A.III.6
7	Generating functions as analytic objects Analytic functions and meromorphic functions Singularities and exponential growth of coefficients	4	Sect B.IV.1 Sect B.IV.2 Sect B.IV.3
8	Closure properties and computable bounds Rational and meromorphic functions Localization of singularities Singularities and functional equations	4	Sect B.IV.4 Sect B.IV.5 Sect B.IV.6 Sect B.IV.7
9	A glimpse of basic singularity analysis theory Coefficient asymptotics for the standard scale Transfers The process of singularity analysis	4	Sect B.VI.1 Sect B.VI.2 Sect B.VI.3 Sect B.VI.4
10	Multiple singularities Tauberian theory and Darboux's method	4	Sect B.VI.5 Sect B.VI.11
11	Sets and the exp–log schema	4	Sect B.VII.2

	Simple varieties of trees and inverse functions		Sect B.VII.3
12	Singularity analysis and probability distributions	4	Sect B.VII.10
13	Saddle-point bounds	4	Sect B.VIII.1 Sect B.VIII.2