UNSW SYDNEY

Course Outline

MATH1081 Discrete Mathematics

School of Mathematics and Statistics

Faculty of Science

Term 1, 2023

Contents

1.Staff

Position	Name	Email	Room*
Director of First Year	Associate Prof Jonathan Kress	j.kress@unsw.edu.au	RC-3073
Course authority Lecturer Numbas contact	Dr Sean Gardiner	sean.gardiner@unsw.edu.au	RC-5108
Assignment contact	Nathan Jackson	n.jackson@unsw.edu.au	

*Staff consultation will take place online and in-person and begin in Week 2. See Moodle for more details.

2.Administrative matters

Contacting the Student Services Office

Please visit the School of Mathematics and Statistics website (located under “Student life & resources”) for a wide range of information on

- School Policies, Forms and Help for Students, go to “Student Services” tab
- Courses, please go to “Undergraduate” > “**Undergraduate courses**” for information on all **course offerings.**
- Latest student news, go to “Student noticeboard”. Notices are posted regularly for your information here.

Please familiarise yourself with the information found in these locations. The School web page is: https://www.unsw.edu.au/science/our-schools/maths

If you cannot find the answer to your queries on the website you are welcome to contact the Student Services Office directly. The First Year Advisor in the Student Services Office is Ms Hilda Cahya. All administrative enquiries concerning first year Mathematics courses should be sent to H Cahya, either:

- By email to ug.mathsstats@unsw.edu.au
- By phone: 9385 7011 (leave message and contact phone number for call to be returned).
- Or in person to the Red Centre building, level 3, room 3072. NB: There is no contact at this office without prior appointment, please email while working remotely.

Change of tutorials, due to timetable clashes or work commitments, advice on course selection and other administrative matters are handled in the Student Services Office. Constructive comments on course improvement may also be emailed to the Director of First Year Mathematics, A/Prof Jonathan Kress. Should we need to contact you, we will use your official UNSW email address of

z[studentnumber]@student.unsw.edu.au

in the first instance. **It is your responsibility to regularly check your university email account. Please state your student number in all emails to the Student Services Office.**

3.Course information

Units of credit: 6

Assumed knowledge: The assumed knowledge for this course is equivalent of a combined mark of at least 100 in the HSC Mathematics and HSC Mathematics Extension 1.

Co-requisite: The formal co-requisite is MATH1131 or MATH1141 or MATH1151. (You must either be taking one of these courses at the same time or have passed one already.)

Teaching times and locations: see the link on the Handbook web page:

Timetable for course MATH1081: https://timetable.unsw.edu.au/2023/MATH1081.html#S1S

Offered in: Terms 1, 2, and 3.

The subject matter of this course is very different from “high school mathematics” and success at high school is no guarantee of success in Discrete Mathematics. In MATH1081 emphasis is placed on reasoned argument and clarity of exposition as well as algebraic and computational skills.

Course summary

The MATH1081 course will enhance your research, inquiry, and analytical thinking abilities as it will provide you with the mathematical language and mathematical techniques to unravel many seemingly unrelated problems. The theory covered will provide good foundation for understanding many problems that arise in all science disciplines, particularly computer science. The mathematical problem-solving skills that you will develop are generic problem-solving skills, based on logical arguments and mathematical language that can be applied in multidisciplinary work. The course will engage you in independent and reflective learning through your independent mastery of a wide range of tutorial problems. You will be encouraged to develop your communication skills through active participation in tutorials, critical analysis of the work of others, and presenting clear, logical arguments when solving problems.

Course aims

The course aims to provide students with foundational knowledge of Discrete Mathematics, broken into five main topics: set theory, number theory, proofs and logic, combinatorics, and graph theory. Students who successfully complete this course will have developed important problem-solving skills and improved their mathematical thinking and communication skills.

Course learning outcomes (CLO)

At the successful completion of this course you (the student) should be able to:

1. State definitions and theorems in the syllabus and apply them to specific examples.
2. Apply the concepts and techniques of the syllabus to solve appropriate problems.
3. Communicate mathematical ideas effectively using correct terminology.
4. Use technology as an aid to communicate mathematical ideas.
5. Recognise and create valid mathematical arguments.

4.Learning and teaching activities

Lecture and Tutorial Schedule

Please note that Lectures commence in week 1 and run to week 10 according to your myUNSW timetable. Lectures may continue into week 11 according to need.

Activity	Monday	Tuesday	Wednesday	Thursday	Friday
LEC 1		12 – 2pm (Weeks 1-5,7-10, ChemSc M17)	4 – 6pm (Weeks 1-5,7-10, CLB 7)		2pm – 3pm (Weeks 1-5,7,9-10, Rex Vowels)
LEC 2		12 – 2pm (Weeks 1-5,7-10, ONLINE)	4 – 6pm (Weeks 1-5,7-10, ONLINE)		2pm – 3pm (Weeks 1-5,7,9-10, ONLINE)
WEB	Pre-recorded lectures are on Moodle as an alternative to live lecture or an extra resource.				
Exam (WEB1)	Refer to https://timetable.unsw.edu.au/2023/MATH1081.html#S1S				
Tutorial					

Note: The Friday 7 April (Week 8) lecture will be cancelled due to public holiday

Students must enroll into a pair of tutorials. Tutorials are compulsory. Web lectures are provided through the Moodle course page as a link to the Lecture videos.

In Term 1 2023 there will be in-person live lectures with limited capacity. These will be streamed online via echo360. A link will be provided on Moodle. These lectures will also be recorded and available to watch at a later time, however, it is recommended that students attend the lectures live online.

There are 5 hours of lectures per week except in Week 6. Lectures commence in Week 1 and run to Week 10. Full details of the timetable are shown in your timetable in myUNSW and the online Handbook (link above).

The material presented is divided into five sections or topics. The approximate lecture numbers for each topic is shown below.

Topics	1	2	3	4	5
Lectures	1 to 8	9 to 15	16 to 28	29 to 39	40 to 45

Classroom Tutorials

Each student enrolled in MATH1081 has been assigned two tutorial time slots as shown in your timetable. Students can change their tutorials via myUNSW until the end of Week 1. After that time, they can only change tutorials by contacting the Maths & Stats Student Services (see page 3) with evidence of a timetable clash or work commitments

Each student will have two tutorials per week with the same tutor, with tutorials in Weeks 1 to 5 and 7 to 10. Attendance at tutorials is compulsory and the roll will be kept in tutorials.

In Term 1 2023, students can enrol in either a face-to-face tutorial, or an online tutorial. The face-to-face tutorials are subject to change depending on conditions within NSW. The Online Classroom Tutorials will use Blackboard Collaborate, a virtual classroom system. This is the same system that is used for lectures. See Moodle for details. A computer with internet access is recommended for attending live classes online.

Weekly Numbas Lessons

In addition to the Classroom Tutorials, MATH1081 has a weekly Numbas lesson in the form of a short set of exercises. These are described below in the Assessment section.

UNSW Moodle

The School of Mathematics and Statistics uses the Learning Management System called Moodle. To log into Moodle, use your zID and zPass at the following URL:

http://moodle.telt.unsw.edu.au

Here you will find announcements, general information, notes, lecture slide, classroom tutorial and homework problems and links to Numbas lessons and assessments.

5.Assessment

Assessment overview

The final mark will be made up as follows:

Assessment task	**Weight**	**CLOs**
Numbas exercises Weekly lessons: 10% for combined best 6 of 9 scores Lab test 1: 10% Lab test 2: 15%	35%	1,2,5
Assignment	15%	1,2,3,4,5
End of term examination	50%	1,2,3,5

To pass this course a student needs a final overall mark of at least 50%. There is no requirement to obtain a pass in any one assessment task.

Each type of assessment is described below in detail.

Note:

- You will be able to view your final exam timetable on myUNSW. Details of when this timetable will be released is available on the university website.

  https://student.unsw.edu.au/dates-and-timetables

- It is very important that you understand the University's rules for the conduct of Examinations and the penalties for **Academic Misconduct Guide**. This information can be accessed through myUNSW at:

  https://student.unsw.edu.au/conduct

- In recent years, there have been cases where severe penalties have been imposed for misconduct in relation to tests and exams in Maths courses.

- UNSW assesses students under a standards based assessment policy. For how this policy is applied within the School of Mathematics and Statistics, please visit the web site:

  https://www.maths.unsw.edu.au/currentstudents/assessment-policies

- For information on how the School implements special consideration policies for assessments during the term and the final examination, refer to the School's website:

  https://www.maths.unsw.edu.au/currentstudents/special-consideration-illness-misadventure

Weekly Numbas Lessons

Each week there will be a Numbas Lesson to complete on Moodle. These lessons will focus on material covered in lectures up to the middle of that week. Instructions will be provided on Moodle. Each Numbas lesson for Week N will be available by Friday of Week N-1, and will have a deadline at 5pm Wednesday of Week N+1. Your best 6 of the 9 weeks will count towards your final mark.

These Numbas Lessons will cover basic skills. The material covered in each might include upcoming topics as preparation to help you get the most out of lectures and tutorials, as well as material already covered in the lectures and tutorials to help you prepare for the lab tests.

You are encouraged to work on these exercises in groups with other students, but you must only enter answers to your questions that you have worked out for yourself.

The weekly Numbas Lessons allow you to check your answers as you go so you should aim to achieve a near perfect score. You can repeat these as many times as you like, and you may find this useful for practice and revision. After each weekly deadline, a revision version will be available but won't count towards your final mark.

Lab Tests

As well as completing the weekly online component of the Numbas Lessons, you will take two Lab Tests based on a similar set of questions. These will be conducted in the computer labs in Week 4 and Week 10, at times specified in your timetable. The Lab Test questions will be provided on Moodle for practice at least one week before the beginning of the tests.

Assignment

The assignment is designed to help you construct rigorous mathematical arguments and communicate mathematical ideas in clear and correct mathematical language. It is comprised of 3 questions covering content from Topics 1-3 that require carefully-written proof solutions. The assignment is broken into three stages. First you will submit a typeset draft version of your solutions to 2 of the 3 assignment questions by the end of Week 5. You will then be allocated another student's draft and tasked with critically analysing their work, with your written review due by the middle of Week 7. Finally, you will use the feedback provided by a peer on your own draft to improve your typeset solutions, with the final submission due by the end of Week 9. You will receive feedback on the peer review that you write and the one that you receive, as well as on your final solutions submission. You will receive a mark out of 10 for the peer review that you write, and a mark out of 20 for your final solutions submission. The first draft submission is not marked, but must be submitted in order to move on to the peer review stage. A penalty of 5% of the assignment total (i.e. 0.75% of your final grade) will be deducted for each day late, up to a maximum of 5 days late, for any of the 3 stages. Submissions more than 5 days (120 hours) late will receive 0 marks. See Moodle for more details.

End of Term Examination

In Term 1 2023 the End of Term Examination will be conducted using Möbius. **The exam will be conducted under supervised conditions in the Red-Centre computer labs during the official exam period.** Very limited exceptions will be allowed for students who are studying offshore in Term 1 2023. The date and time of the final examination will be available on myUNSW and further details of the exam arrangements, including for students unable to come to Sydney, will be available on Moodle when the final exam timetable is released.

The end of term exam covers material from the whole syllabus. The best guide to the style and level of difficulty is the past exam papers. The course pack contains a book of past exam papers with worked solutions and additional past exams will be posted on Moodle. Examination questions are, by their nature, different from short test questions. They may test a greater depth of understanding. The questions will be longer, and sections of the course not covered in other assessments will be examined.

This term's exam will be closest in format to the 2020, 2021 and 2022 exams. Earlier exams are also good for practice. More specific information on the format will be provided on Moodle close to the end of Term.

The assessment tasks during the term allow repeated attempts over an extended period and resources are available to students attempting these assessments. As a result, students should be aiming for a high mark in the pre-exam assessment and this indicates significant progress towards achieving the learning outcomes of this course. The exam is time limited and has more complex questions. Therefore, a high mark in the pre-exam assessment is not always an accurate indication of the final course mark.

Schedule of all assessments

Lectures and tutorials run during Weeks 1 to 5 and 7 to 10. The table below gives the schedule of all assessments.

Week	Assignment/lab tests	Weekly Numbas Lessons
1		Start work on your first Weekly Numbas Lesson
2		Week 1 Numbas Lesson due Wednesday 5pm
3		Week 2 Numbas Lesson due Wednesday 5pm
4	Lab Test 1 (EXM class in timetable)	Week 3 Numbas Lesson due Wednesday 5pm
5	Assignment draft due Friday 5pm	Week 4 Numbas Lesson due Wednesday 5pm
6	Flexibility Week	
7	Assignment peer review due Wednesday 5pm	Week 5 Numbas Lesson due Wednesday 5pm
8		Week 7 Numbas Lesson due Wednesday 5pm
9	Assignment final submission due Friday 5pm	Week 8 Numbas Lesson due Wednesday 5pm
10	Lab Test 2 (EXM class in timetable)	Week 9 Numbas Lesson due Wednesday 5pm Week 10 Numbas Lesson due Sunday 11:59pm*
11	Monday to Thursday: Study break Friday: Start of exams – Check myUNSW for exam timetable	

* The last Weekly Numbas Lesson will remain available until Week 11 Wednesday 5pm.

6.Expectations of students

School and UNSW Policies

The School of Mathematics and Statistics has adopted a number of policies relating to enrolment, attendance, assessment, plagiarism, cheating, special consideration etc. These are in addition to the Policies of The University of New South Wales. Individual courses may also adopt other policies in addition to or replacing some of the School ones. These will be clearly notified in the Course Initial Handout and on the Course Home Pages on the Maths & Stats web site.

Students in courses run by the School of Mathematics and Statistics should be aware of the School and Course policies by reading the appropriate pages on the Maths & Stats web site starting at:
https://www.unsw.edu.au/science/our-schools/maths/student-life-resources/student-services/assessment-policies

The School of Mathematics and Statistics will assume that all its students have read and understood the School policies on the above pages and any individual course policies on the Course Initial Handout and Course Home Page. Lack of knowledge about a policy will not be an excuse for failing to follow the procedure in it.

Academic Integrity and Plagiarism

UNSW has an ongoing commitment to fostering a culture of learning informed by academic integrity. All UNSW staff and students have a responsibility to adhere to this principle of academic integrity. Plagiarism undermines academic integrity and is not tolerated at UNSW. *Plagiarism at UNSW is defined as using the words or ideas of others and passing them off as your own.*

The **UNSW Student Code** provides a framework for the standard of conduct expected of UNSW students with respect to their academic integrity and behaviour. It outlines the primary obligations of students and directs staff and students to the Code and related procedures.

In addition, it is important that students understand that it is not permissible to buy essay/writing services from third parties as the use of such services constitutes plagiarism because it involves using the words or ideas of others and passing them off as your own. Nor is it permissible to sell copies of lecture or tutorial notes as students do not own the rights to this intellectual property.

If a student breaches the Student Code with respect to academic integrity, the University may take disciplinary action under the **Student Misconduct Procedure**.

The UNSW Student Code and the Student Misconduct Procedure can be found at: https://student.unsw.edu.au/plagiarism

An online Module "Working with Academic Integrity" (https://student.unsw.edu.au/aim) is a six-lesson interactive self-paced Moodle module exploring and explaining all of these terms and placing them into your learning context. It will be the best one-hour investment you've ever made.

Plagiarism

Plagiarism is presenting another person's work or ideas as your own. Plagiarism is a serious breach of ethics at UNSW and is not taken lightly. So how do you avoid it? A one-minute video for an overview of how you can avoid plagiarism can be found https://student.unsw.edu.au/plagiarism.

Detection of academic misconduct

The School of Mathematics and Statistics uses a variety of means to detect and investigate potential academic misconduct in assessments, including the use of data from University systems and websites.

7.Readings and resources

Course Pack

Your course pack should contain the following two items:

- *Problem Sets Booklet*
- *Past Exam Papers and Solutions Booklet*

These items can also be downloaded from UNSW Moodle, but many students find the hardcopy more efficient for study.

*NB: The **Course Outline** will be provided through the Moodle site and / or School web site, containing:*

Information on administrative matters, lectures, tutorials, assessment, syllabus, lab tests, assignment, special consideration and additional assessment.

Textbook

S.S. Epp, "Discrete Mathematics with Applications", Fourth Edition, 2011 OR Second (or Third) Edition, PWS 1995.

J Franklin and A. Daoud, "Introduction to Proofs in Mathematics", Prentice Hall, 1988 or "Proof in Mathematics: An Introduction", Quakers Hill Press, 1995.

Reference Books

Any book with "Discrete Mathematics" and many with "Finite Mathematics" in their title should help. Previous texts include K.H. Rosen, "Discrete Mathematics and its Application" and K. Kalmanson, "An Introduction to Discrete Mathematics and its Applications". A more advanced reference is K. Ross and C.R.B. Wright, "Discrete Mathematics". For interesting applications within Computer Science, try the three part classic – D.E.Knuth, "The Art of Computer Programming".

8.Getting help outside tutorials

Staff Consultations

From week 2 there will be a roster which shows for each hour of the week a list of names of members of staff who are available to help students in the first year mathematics courses, no appointment is necessary. This roster will be announced in the Moodle course page at the end of week 1 and can be located by visiting web page:

https://www.unsw.edu.au/science/our-schools/maths/student-life-resources/student-services/consultation-mathematics-staff

Mathematics Drop-in Centre

The Maths Drop-in Centre provides free help to students with certain first and second year mathematics courses. All first year MATH courses are supported. The Maths Drop-in Centre operates online via Moodle. Some limited in-person sessions may also be arranged. For opening times, week the Drop-in Centre Moodle page.

The Maths Drop-in Centre schedule will be available on the Schools website and Moodle page below by the start of week 1. Please note that no appointment is necessary, this is a drop-in arrangement to obtain one-on-one help from tutors

https://www.unsw.edu.au/science/our-schools/maths/student-life-resources/student-services/mathematics-drop-in-centre

Additional support for students

ELISE (Enabling Library and Information Skills for Everyone)

ELISE is designed to introduce new students to studying at UNSW.

Completing the ELISE tutorial and quiz will enable you to:

- analyse topics, plan responses and organise research for academic writing and other assessment tasks
- effectively and efficiently find appropriate information sources and evaluate relevance to your needs
- use and manage information effectively to accomplish a specific purpose
- better manage your time
- understand your rights and responsibilities as a student at UNSW
- be aware of plagiarism, copyright, UNSW Student Code of Conduct and Acceptable Use of UNSW ICT Resources Policy
- be aware of the standards of behaviour expected of everyone in the UNSW community
- locate services and information about UNSW and UNSW Library

Some of these areas will be familiar to you, others will be new. Gaining a solid understanding of all the related aspects of ELISE will help you make the most of your studies at UNSW.

The *ELISE* training webpages:
https://subjectguides.library.unsw.edu.au/elise/aboutelise

Equitable Learning Services (ELS)

If you suffer from a chronic or ongoing illness that has, or is likely to, put you at a serious disadvantage, then you should contact the Equitable Learning Services (previously known as SEADU) who provide confidential support and advice.

They assist students:

- living with disabilities
- with long- or short-term health concerns and/or mental health issues
- who are primary carers
- from low SES backgrounds
- of diverse genders, sexes and sexualities
- from refugee and refugee-like backgrounds
- from rural and remote backgrounds
- who are the first in their family to undertake a bachelor-level degree.

Their web site is: https://student.unsw.edu.au/els/services

Equitable Learning Services (ELS) may determine that your condition requires special arrangements for assessment tasks. Once the School has been notified of these, we will make every effort to meet the arrangements specified by ELS.

Additionally, if you have suffered significant misadventure that affects your ability to complete the course, please contact your Lecturer-in-charge in the first instance.

Academic Skills Support and the Learning Centre

The Learning Centre offers academic support programs to all students at UNSW Australia. We assist students to develop approaches to learning that will enable them to succeed in their academic study. For further information on these programs please go to:

http://www.lc.unsw.edu.au/services-programs

Other Supports

- The Current Students Gateway: https://student.unsw.edu.au/
- Academic Skills and Support: https://student.unsw.edu.au/academic-skills
- Student Wellbeing, Health and Safety: https://student.unsw.edu.au/wellbeing
- UNSW IT Service Centre: https://www.it.unsw.edu.au/students/index.html

9. Applications for Special Consideration

If you are unable to complete an assessment on time or during the proscribed period due to illness or other reason beyond your control, you can apply for special consideration.

For all information on Special Consideration, including the circumstances that are covered or excluded and how to apply, see the Special Consideration web site:

https://student.unsw.edu.au/special-consideration

Please note that the application is not considered by the Course Authority, it is considered by a centralised team of staff at the Nucleus Student Hub.

The central team will advise you, by email to your UNSW student email, of the outcome of your application and the date of any supplementary assessment or extension as appropriate.

For final exams with special consideration granted, the Exams Unit will email the rescheduled “supplementary exam” date, time and location to your student zID email account directly. Please ensure you regularly check your student email account (zID account) for this information.

The supplementary exam period/dates can be found at this web site:

https://student.unsw.edu.au/exam-dates

Please ensure you are aware of these dates and that you are available during this time.

10. Syllabus

References are to the textbook by Epp, unless marked otherwise. F indicates the textbook by Franklin and Daoud and R indicates the book *Discrete Mathematics with Applications* by K.H. Rosen (6th edition). The UNSW Library has multiple copies of Rosen numbered P510/482A,B,C, etc.

The references shown in the righthand column are *not* intended to be a definition of what you will be expected to know. They are just intended as a guide to finding relevant material. Some parts of the course are not covered in the textbooks and some parts of the textbooks (even in sections mentioned in the references below) are not included in the course.

In the Reference column below, column A refers to Epp 3rd edition, and Rosen 2nd edition, while column B to Epp 4th edition and Rosen 6th edition.

Within sections of the course, the topics may not be covered in exactly the order in which they are listed below.

Topic	References A	References B
1: Sets and Functions		
Sets, subsets, power sets. Equality, cardinality	5.1, 5.3	1.2, 6.1, 6.3
Set operations: union, intersection, difference.	5.1	6.1
Universal sets, complements. Cartesian product.	5.2	6.2
Functions. Domain, codomain and range. Arrow diagrams.	7.1, 3.5	1.3, 7.1, 4.5
Ceiling and floor functions. Images and inverse images of sets. Injective (one-to-one), surjective (onto) and bijective functions.	7.3	7.2
Composition of functions	7.4	7.3
Inverse functions.	7.2	7.2
2: Number Theory and Relations		
Prime numbers and divisibility.	3.1, 3.3	4.1, 4.3
Fundamental Theorem of Arithmetic.	3.3	4.3
Euclidean algorithm.	3.8	4.8
Modular arithmetic.	3.4	4.4, 8.4
Solving linear congruences.	R2.5	R3.7
General relations.	10.1	8.1

Reflexivity, symmetry, anti-symmetry, and transitivity.	10.2	8.2
Equivalence relations.	10.3	8.3
Partially ordered sets and Hasse diagrams.	10.5	8.5

3: Logic and Proofs

Proof versus intuition. Direct proof.	F1	F1
Proof of universal statements, proof by exhaustion of cases.	2.1, F2, F3	3.1, F2, F3
Proof of existential statements. Constructive and non-constructive proofs. Counterexamples.	2.1, 3.1, F4, F6	3.1, 4.1, F4, F6
Negation of quantified statements.	2.1	3.2
Contrapositive, indirect proof, proof by contradiction.	1.2, 3.6, F6, 3.7	2.2, 4.6, 4.7, F6
Quantifiers, statements with multiple quantifiers.	2.1	3.1, 3.2
Common mistakes in reasoning. Converse and inverse fallacies.	2.3, 3.1	3.3, 3.4, 4.1
Mathematical induction.	4.2-4.4, F8	5.2-5.4, F8
Propositions, connectives, compound propositions.	1.1	2.1
Truth tables. Tautology, contingency, contradiction. Logical equivalence.	1.1	2.1
Implication, converse, inverse, biconditional.	1.2	2.2
Rules of inference.	1.3	2.3
	Note: In addition to the sections of Epp mentioned above, sections 4.2–4.5 and 4.7 (3.2–3.5,3.7 for edition 3) provide many useful worked examples of constructing proofs in elementary number theory.	

4: Combinatorics

Counting.	6.1	9.1
Multiplication rule.	6.2	9.2
Addition rule.	6.3	9.3

Principle of Inclusion-Exclusion.	6.3	9.3
Pigeonhole principle.	7.3	9.4
Permutations and combinations.	6.4, 6.5	9.5, 9.6
Binomial and multinomial theorem.	6.7, R4.6	9.7, R5.4
Recurrence relations.	8.2, 8.3	5.6, 5.7, 5.8
Recursively defined sequences.	8.1	5.9

5: Graph Theory

Basic terminology. Graphs and multigraphs. Directed graphs, subgraphs, complementary graphs.	11.1	10.1
Degree, the Handshaking Lemma.	11.1	10.1
Bipartite graphs.	11.1	10.1
Adjacency matrices.	11.3	10.3
Isomorphism, isomorphism invariants.	11.4	10.4
Walks, trails and tours, paths and circuits. Euler and Hamilton walks. Connected graphs, connected components.	11.2	10.2
Planar graphs. Euler's formula. Dual graphs. Necessary conditions for planarity. Kuratowski's Theorem.	R7.7	R9.7
Trees, spanning trees.	11.5, 11.6	10.5, 10.7
Weighted graphs. Minimal spanning trees. Kruskal's and Dijkstra's algorithms.	11.6	10.6, 10.7