Tutorial Letter 101/3/2018

Theoretical Computer Science III

COS3701

Semesters 1 and 2

School of Computing

This tutorial letter contains important information about your module.

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Dear Student,

1 INTRODUCTION

Welcome to the Theoretical Computer Science III module (COS3701). We trust that you will find this module stimulating and interesting, and wish you a successful semester.

This is a semester module presented by the School of Computing. In this module we proceed with our interplay between languages and machines. The knowledge you have gained from COS2601 is of utmost importance. Towards the end of COS3701 you will be introduced to the Turing Machine (TM). The TM was formally published in 1936 by Alan Mathison Turing. The TM is believed to be the ultimate computing machine. Note that it is believed that there do not exist functions that can be defined by humans, of which the calculation can be described by any well-defined algorithm that can be performed or taught by people, that cannot be computed by TMs. Keep in mind the TM predated the invention of the computer itself. Turing was not analysing an example of a computer in front of him – he was engaged in inventing the beast. It was directly from Turing's ideas in his work on mathematical models that the first computers (as we know them) were built. You should agree that this is a demonstration that nothing is more practical than a good abstract theory!

Do not hesitate to contact your lecturers (on *my*Unisa, by email, or by telephone) if you are experiencing problems with the content of this tutorial letter or any aspect of the module. We sincerely hope that you find this module, as well as your online learning experience, interesting and rewarding and trust that you will complete the module successfully.

Because this is a blended module (that is, it has some printed and some online material), you need to use *my*Unisa to study and complete the learning activities for this module. You need to visit the website on *my*Unisa for COS3701 frequently. The website for your module is COS3701-18-S1/S2.

1.1 To get started…

Because some of the learning material is online, you need to go online to see your study materials and read what to do for the module. Go to the website here: https://my.unisa.ac.za and login with your student number and password. You will see COS3701-18-S1/S2 in the row of modules in the orange blocks across the top of the webpage. Remember to also check in the -more- tab if you cannot find it in the orange blocks. Click on the module you want to open.

2 MODULE FORMAT: COS3701

2.1 Blended module

Please note that this module is offered in a blended format (which means that though all the material will be available online, some material will be printed and some will be available only online).

All study material for this module will be available on *my*Unisa. It is thus very important that you register on *my*Unisa and access the module site on a regular basis. You must be registered on *my*Unisa to be able to access your learning material, submit your assignments, gain access to various learning resources, "chat" to your lecturer/e-tutor and fellow students about your studies

and the challenges that you might encounter, and to participate in online discussion forums. Importantly, *my*Unisa contains the **Learning Units** tool from which you will only be able to access the study material for this module if you have registered and have access to *my*Unisa.

2.2 Printed materials to support the blended module

The only printed document that you will received for this module is the tutorial letter (TL101) (this document). Other tutorial matter will not be printed (such as assignment solutions that are issued as tutorial letters 201, 202, 203 and 204). These documents will all be available under **Additional Resources** on the *my*Unisa page.

Remember, the printed documents are a back-up to everything that is found online, on *my*Unisa. There are no extra things there**. In other words, you should NOT wait for the printed support materials to arrive to start studying.**

Please consult the *Study @ Unisa* publication for more information on the activation of your *my*Life email address as well as obtaining access to the *my*Unisa module site.

3 PURPOSE OF AND OUTCOMES FOR THE MODULE

3.1 Purpose

COS3701 deals with context free as well as recursive enumerable languages. Context Free Grammars (CFGs), which generate context free languages, are introduced as well as Push Down Automata (PDAs) which accept CFGs. Two types of machines namely, nPDAs ($n > 1$) and Turing Machines (TMs), which accept a variety of formal languages, including recursive enumerable languages are dealt with. If students understand TMs, the theoretical predecessor of the computer, then they should start to realize what is computable and what not. In order to provide an overview of formal languages the Chomsky hierarchy is presented.

This module forms part of a Computer Science major, supporting further studies and applications in the sector of Compiler Development, Computer Programming, Bioinformatics and Linguistics. These concepts and skills contribute to the development of the computing field in southern Africa, Africa, and globally.

3.2 Outcomes

After completing this module, a student should be able to:

- Define context free grammars (as formal mathematical presentations), using a variety of defined mathematical tools for evidence (including definitions, theorems and operators).
- Construct mathematical proofs in a clear and concise way using abstract mathematical reasoning techniques. Types of proofs include proofs by constructive algorithms, direct proofs, proofs by machines, proofs by decidability algorithms and proofs by reductio ad absurdum (pumping lemma).
- Construct context free language (CFL – Type 2 grammars, Chomsky Hierarchy) machine acceptors, by drawing these machine acceptors, namely Push Down Automata (PDAs), through applying the relevant definitions and theorems.
- Construct Turing Machines and nPDAs for *n* greater than 1, which accept context sensitive grammars (Type 1 grammars, Chomsky Hierarchy) and recursive enumerable languages (Type 0 grammars, Chomsky Hierarchy).

- Critically analyse and synthesise provided TMs to determine which languages are accepted by them.
- Perform algorithms on CFGs to obtain a product, sum or Kleene closure of a maximum of two CFGs in the case of the sum and the product and one CFG in the case of the Kleene closure. Proving thereby, for specific CFLs, that they are closed under the product, sum and Kleene closure. In general, it is proven in Cohen that all CFLs are closed under the product, sum and Kleene closure.

4 LECTURER AND CONTACT DETAILS

4.1 Lecturer

You are welcome to contact a COS3701 lecturer. The names and telephone numbers of the lecturers will be supplied in a COSALL tutorial letter, and can also be found on the module site on *my*Unisa. You should also check the home page of the COS3701 site on *my*Unisa to see if there have been any changes to the lecturing staff for this module.

When you contact the lecturers, please do not forget to **always** include your student number and module code. This will help the lecturers to assist you.

4.2 Department

Should you have difficulty in contacting your lecturers, you may phone the general number of the School of Computing at 011 670 9200. Your message will then be conveyed to the relevant lecturer. Remember to provide your student number together with the relevant module code.

4.3 University

To contact the University, you should follow the instructions in the *Study @ Unisa* brochure. Remember to have your student number available when you contact the University.

5 MODULE-RELATED RESOURCES

5.1 Prescribed books

You need the prescribed textbook:

COHEN, DANIEL I.A. Introduction to Computer Theory, 2nd edition. John Wiley & Sons, 1997.

Note that there is a custom version of the textbook which was printed specially for the COS2601 and COS3701 Unisa modules. That version is equivalent to the normal 2nd Edition.

We cover Parts II and III of the textbook. The textbook is available from the official university booksellers and you are required to obtain your own copy. Please consult the list of official booksellers and their addresses in *Your Service Guide @ Unisa*. If you have any difficulties with obtaining books from these bookshops, please contact the Registrar as soon as possible. Note that Cohen is prescribed for COS2601 too, thus you probably have a copy of the book already.

Note that not every page of the textbook is prescribed material. The online learning units will guide you through the material in Cohen that is covered in this module. The syllabus for this module is divided into four sections and your comprehension of each section is tested in an assignment. The sections are as follows:

Section	***Cohen*, 1997 Edition**
1	Chapters 12 – 15
2	Chapters 16 – 18
3	Chapters 19 – 22
4	Chapters 23 – 25

Parts of these chapters are not prescribed, and one whole chapter – Chapter 20 (1997 edition) can be omitted. More detail on this appears on the module *my*Unisa page.

Errata relevant to this module are listed on the *my*Unisa module page.

5.2 Recommended books

Should you wish to know more about a particular topic, you may consult the following book. (Please note that this book is not necessarily included in the study collection of the Unisa library.)

MARTIN, J. Introduction to Languages and the Theory of Computation. 3rd edition. McGraw-Hill, 2003.

5.3 Electronic Reserves (e-Reserves)

There are no electronic reserves for this module.

5.4 Free computer and internet access

Unisa has entered into partnerships with establishments (referred to as Telecentres) in various locations across South Africa to enable you (as a Unisa student) free access to computers and the Internet. This access enables you to conduct the following academic related activities: registration; online submission of assignments; engaging in e-tutoring activities and signature courses; etc. Please note that any other activity outside of these are for your own costing e.g. printing, photocopying, etc. For more information on the Telecentre nearest to you, please visit www.unisa.ac.za/telecentres.

6 STUDY PLAN

The study plan below should help you get through all the work that needs to be covered this semester.

Note that the dates in normal text refer to the first semester and those in italics refer to the second semester.

Tuition Week	**Dates (week starting)**	**Work to do**	**Assignments due**
1	12 February *23 July*	Revision of COS2601 Material Chapter 12 – Context free grammars	
2	19 February *30 July*	Chapter 13 – Grammatical Format	
3	26 February *6 August*	Chapter 14 – Pushdown Automata	
4	5 March *13 August*	Chapter 15 – CFG = PDA Work on assignment 1	
5	12 March *20 August*	Finalise assignment 1 for submission Chapter 16 – Non-context Free Languages	Assignment 1 due 12 March *Assignment 1 due 20 August*
6	19 March *27 August*	Chapter 17 – Context Free Languages	
7	26 March *3 September*	Chapter 18 – Decideability Work on assignment 2	
8	2 April *10 September*	Complete assignment 2 Chapters 19 – Turing Machines	Assignment 2 due 3 April *Assignment 2 due 10 September*
9	9 April *17 September*	Chapter 21 – Minsky's Theorem	
10	16 April *24 September*	Chapter 22 – Variations on the TM	
11	23 April *1 October*	Chapters 23 and 24 – TM Languages & The Chomsky Hierarchy	Self assessment assignment 03 completed 23 April or *1 October*
12	30 April *8 October*	Chapters 24 and 25 – The Chomsky Hierarchy & Computers Revision	
13	7 May *15 October*	Exams commence Revision until exam date.	Self assessment assignment 04 completed 7 May or *15 October*

7 ASSESSMENT

7.1 Assessment plan

Below is a summary of the formal assignments as they occur in each semester.

Semester	Assignment	Due date	Unique assignment number
1	01	12 March 2018	712235
	02	3 April 2018	779950
2	01	20 August 2018	826802
	02	10 September 2018	842179

There are also two self-assessment assignments numbered 03 and 04 respectively.

Note that you gain admission to the examination for COS3701 by submitting Assignment 01 by the due date.

The assignment questions can be found in section 8 below.

7.2 Submission of assignments

You should submit your assignments electronically via *my*Unisa as PDF files.

The steps to be followed when you submit an assignment via *my*Unisa are as follows:

- Go to *my*Unisa at https://my.unisa.ac.za
- Log on with your student number and password.
- Choose the relevant module (COS3701) in the orange block.
- Click on assignments in the menu on the left-hand side of the screen.
- Click on the assignment number of the assignment that you want to submit.
- Follow the instructions.

8 ASSIGNMENT QUESTIONS

ASSIGNMENT 01 (Semester 1)

Note: Solutions to selected problems in the prescribed book are provided on the module page.

Unique number:	**712235**
Due date:	**12 March 2018**
Material to be tested:	**Cohen, Chapters 12-15**
Weight towards semester mark:	**50%**

Please provide detailed solutions to all the questions. It is possible that not all these questions will be marked. We will decide which of them (or all) to mark and you will not be informed in advance about the decision.

All references are to the 1997 edition of *Cohen*.

If you submit electronically via *my*Unisa then your assignment MUST be in .PDF format.

1. Problem 1 on page 254.
2. Problem 8(ii) on page 256.
3. Problem 15(iii) on page 256-257.
4. Problem 1(iv) on page 285.
5. Problem 11(iii) on page 287.
6. Convert the grammar below to CNF.

   (*Hint*: Consult the appropriate learning unit in your online study material.)

   S → aX | Yb
   X → ZXYZ | a
   Y → b | bY | Λ
   Z → a | Λ

7. Problem 4(ii) on page 286.
8. Build a DPDA that accepts the language L = $\{(ab)^n(aab)b^{2n} \mid n \geq 0\}$.

ASSIGNMENT 02 (Semester 1)

Note: Solutions to selected problems in the prescribed book are provided on the module page.

Unique number:	**779950**
Due date:	**3 April 2018**
Material to be tested:	**Cohen, Chapters 16-18**
Weight towards semester mark:	**50%**

Please provide detailed solutions to all the questions. It is possible that not all these questions will be marked. We will decide which of them (or all) to mark and you will not be informed in advance about the decision.

All references are to the 1997 edition of *Cohen*.

If you submit electronically via *my*Unisa then your assignment MUST be in .PDF format.

1. Build a DPDA to show that the language $L = \{(ab)^n aaa(ba)^{n-2} \mid n > 2\}$ is deterministic context free.
2. Prove that the language $L = \{a^{n+1}b^{2n+1}(aa)^n b \mid n > 0\}$ is non context free. Use the pumping lemma with length.
3. Problem 2(i) on page 398.
4. Given that $L_1 = (ab)^*$ and $L_2 = (a+b)^*bb(a + b)^*$. Find grammars for L_1 and L_2. Then use Theorem 36 to find $L_1 + L_2$.
5. Problem 1(ii) on page 429. Show all the steps.
6. Problem 3(ii) on page 429. Show all the steps.
7. Problem 8 on page 430. Show every step of your solution.

ASSIGNMENT 01 (Semester 2)

Note: Solutions to selected problems in the prescribed book are provided on the module page.

Unique number:	**826802**
Due date:	**20 August 2018**
Material to be tested:	**Cohen, Chapters 12-15**
Weight towards semester mark:	**50%**

Please provide detailed solutions to all the questions. It is possible that not all these questions will be marked. We will decide which of them (or all) to mark and you will not be informed in advance about the decision.

All references are to the 1997 edition of *Cohen*.

If you submit electronically via *my*Unisa then your assignment MUST be in .PDF format.

1. Problem 2 on page 254.
2. Problem 8(i) on page 256.
3. Problem 15 (iv) on page 256 -257.
4. Problem 1(vii) on page 285.
5. Problem 11(iv) on page 287.
6. Convert the grammar below to CNF.

   (*Hint*: Consult the appropriate learning unit in your online study material.)

   $S \rightarrow aX \mid Yb \mid XYZ$
   $X \rightarrow XY \mid \Lambda$
   $Y \rightarrow b \mid bY \mid \Lambda$
   $Z \rightarrow a \mid \Lambda$

7. Problem 6(i) on page 286.
8. Draw a DPDA that accepts the language $L = \{ba(bb)^{n+1}a^{n-1} \mid n > 1\}$.

ASSIGNMENT 02 (Semester 2)

Note: Solutions to selected problems in the prescribed book are provided on the module page.

Unique number:	**842179**
Due date:	**10 September 2018**
Material to be tested:	**Cohen, Chapters 16-18**
Weight towards semester mark:	**50%**

Please provide detailed solutions to all the questions. It is possible that not all these questions will be marked. We will decide in advance which of them (or all) to mark and you will not be informed in advance about the decision.

All references are to the 1997 edition of *Cohen*.

If you submit electronically via *my*Unisa then your assignment MUST be in .PDF format.

1. Build a DPDA to show that the language L = $\{(aa)^{n+1}b^{n-1}aa \mid n > 0\}$ is deterministic context-free.
2. Prove that the language L = $\{ba^nb^{2n}a^{n+1} \mid n > 0\}$ is non-context free. Use the pumping lemma with length.
3. Problem 2(ii) on page 398.
4. Given that $L_1 = (ab)^*$ and $L_2 = (a + b)^*bb(a + b)^*$.

   Find grammars for L_1 and L_2. Then use Theorem 37 to find L_1L_2.
5. Problem 1(v) on page 429. Show every step in your solution.
6. Problem 3(iv) on page 429. Show all the steps.
7. Problem 9 on page 430. Show every step of your solution.

ASSIGNMENT 03 (Semesters 1 and 2)

Material to be tested: Chapters 19 – 22

Due date, Semester 1: 23 April 2018

Due date, Semester 2: 01 October 2018

Marking: Self-assessment solutions will be provided in Tutorial Letters

All references are to the 1997 edition of *Cohen*. Do not use the subroutines INSERT and DELETE.

1. Problem 6(ii) on page 454.
2. Problem 19(i) on page 456.
3. Draw a TM which
   - accepts all words of odd length,
   - crashes on all words of even length which end on *a*, and loops forever on all other words.

   In answering this question, you may assume that the character # has already been inserted at the beginning of the tape.
4. Build/design a TM that determines whether a given word contains at least one instance of the substring aba. If it does then the TM should write a T on the tape after the input word.
5. Build/design a TM that
   - accepts all words of the form $aba(c)^{+}bab$,
   - loops forever on all words that start with b, and
   - rejects all other words.
6. Build a 2PDA that accepts the language

   $$\{ a^{n+1}b^{n+2}c^{n} \mid n > 0 \}.$$

ASSIGNMENT 04 (Semesters 1 and 2)

Material to be tested: Cohen, Chapter 23 - 25

Due date, Semester 1: 7 May 2018

Due date, Semester 2: 15 October 2018

Marking: Self-assessment solutions will be provided in Tutorial Letters

All references are to the 1997 edition of *Cohen*.

1. Problem 1(i) on page 562. ODDPALINDROME is defined on page 204.
2. Let *T* be the Turing machine in problem 13(v) on page 562 - 563. What are the languages accept(*T*), reject(*T*) and loop(*T*)?
3. Problem 13(v) on page 562-563.
4. Run the word in CWL which you found in Question 3 on its TM to determine whether or not it is a word of the language ALAN.
5. Problem 15(ii) on page 564.
6. Problem 8(iv) on page 591.
7. Build a TM that takes in three numbers in unary encoding and leaves only the smallest of them on the tape.

9 CONCLUSION

Do not hesitate to contact your lecturers by email if you are experiencing problems with the content of this tutorial letter or any aspect of the module.

The COS3701 lecturers hope that you will enjoy the module and wish you success. Note, however, that your success depends on your own efforts – work hard, do your assignments, etc. and you are much more likely to be successful!