MAD 3512 – THEORY OF ALGORITHMS          FLORIDA INT'L UNIV.

INFORMATION SHEET (Jan. 9th, 2024)                                   SPRING 2024

INSTRUCTOR:  Prof. Ram,   Office hours: 12:45pm-1:45pm & 3:30pm-4:55pm Tu &Th.

Prof Ram's homepage: <http://faculty.fiu.edu/~ramsamuj/>  Prof Ram's e-mail: [ramsamuj@fiu.edu](mailto:ramsamuj@fiu.edu)

LA Hours: Mr. Michael ILYIN (via Zoom) 10am-12pm Mon, 10am-11am Wed, & Fri. 5pm-8pm.

Mr. Michael ILYIN ZOOM’s Meeting ID: **812 959 4200** Code: **Mi2023** .

PREREQUISITE:  MAD 2104 (CS majors also need COT 3420). A student who doesn't have

good knowledge of Proofs & Abstract Mathematics has little chance of succeeding in this course.

TEXTBOOK:   An Introduction to Formal Languages and Automata by Peter Linz, **7th Edition** (D.C. Heath & Co., 2022). [The 6th ed. of the text is acceptable, but 7th ed. is the official text.]

SYLLABUS:    Below are the relevant sections for about 94% of the course.  
              Languages & Regular Expressions (REX):  1.2,  1.3,  3.1

              Context-Free Grammars (RLG & CFG):  1.2,  3.3,  5.1,  5.2, 5.3  
              Finite Automata (DFA, NFA, GFA):            2.1,  2.2,  2.3,  2.4\*  
              Regular & Non-regular languages:           3.2, 3.3, 4.1, 4.2, 4.3  
              Turing Machines & Computation (TM):   9.1, 9.2, 9.3, 10.3\*, 10.4, 11.1, 11.4  
              Recursive Functions & Complexity:       12.1, 12.2, 13.1, 14.1, 14.3\*

The sections marked with an asterisk may be only partially covered. The other 8% (not in the text) consists of further details about regular expressions, recursive functions, and r.e. sets.

EXAM & ATTENDANCE POLICIES:

1. For each exam you are required to bring your Student ID and a blank blue exam booklet.

(8"x11" available from FIU bookstore). No notes, calculators or cellphones are allowed.

2. A make-up test for Exam #1 will be given - only if there is a verifiable case of illness or

emergency. If you miss Exam #2 for one of the same reasons that test will be discounted,

your grade will be calculated out 260, and you won't be eligible for an IN grade.   
 3. Any misconduct will be reported and dealt with according to the Code of Student Conduct.

4. Sanctioned religious holidays can be accommodated with early notification (1st wk classes).  
 5. Attendance & class participation (40 pts): 3 pts is deducted for each absence or missed exam.

Attendance is mandatory. FIU will give you an automatic **F for less than 60% attendance**.

SCHEDULE OF EXAMS: No calculators, cell-phones, or notes are allowed in the exams.

Test #1 (**100** points): **THURSDAY,**  **FEB. 22nd, 01:45pm - 03:15pm**

Test #2 (**100** points): **THURSDAY,** **APR. 11th, 01:45pm - 03:15pm**

Final Exam (**160** points): **THURSDAY,**  **APR. 25th, 11:45am - 02:00pm**\*

**(40** pts**)** Attendance & class participation: 3 pts is deducted for each absence or missed exam.

\* The final exam will be comprehensive - please note the time is earlier than the regular class.

GRADING SCHEME:  The grades will be assigned as indicated below.

F        D    D     D    C      C      C+     B-   B        B+     A-         A

|           |         |         |         |          |         |          |           |          |          |           |    |   
 0%     **48**      52       56      **60**      64      68       72      76       **80**        85     90     100%

**0** **192pts**  **240pts** 288pts **320pts** 360pts **400pts**

HOLIDAYS:  Mon. Jan. 15th (M. L. King Day), Spring Break (Mon-Sat): Feb. 26th - Mar. 2nd.  
DEADLINES: For add/drop (no liability) - Jan 16th. For DR/WI grade (no refund) - Mar. 18th.

**DETAILS FOR GETTING EXEMPT FROM AN EXAM & FOR GETTING AN “IN” GRADE.**

1. The first (and most important) rule at FIU is that each professor should treat every student in the same uniform way - unless we get documentation from an independent authority (such as the FIU Health Clinic, the FIU DRC, or an MD (medical doctor), etc.) or from a supervisor of the professor (such as the Division Chair-person, the Department Chair-person, or the Dean of the relevant College, etc.) to do otherwise. If the professor does not abide by this first rule, they can be fired.

2. So if a student is not feeling physically or mentally well before an exam, they should contact the FIU Health Clinic, or the FIU Counselling & Psychological Services (see below for the links), or your doctor – and get a signed letter that specifically says: ”Ms. X (or Mr. Y) is medically unable to take any exam on such and such a day. Please excuse Ms. X (or Mr. Y) from taking this exam on this specific day.” We are not authorized to know of the specific medical condition you may have. *You will lose 3 pts for being absent - because you did not come or participate in class*.

3. If this is the first exam in the course, the professor will attempt to give the student a make-up exam (if the student is able to take such an exam before the DR deadline) - so that the student can be have some feed-back about their performance before the deadline for getting a DR grade). Because of time constraints it is not possible to give a make–up exam for the second in-semester test before the final exam.

4. In order to get an “IN” grade (in which just the final exam needs to be completed during the next semester), a student must complete more than 50% of the graded material (i.e., the first two exams) and earn a passing grade so far. So if a student was exempted (for any of the reasons above) from the second exam, then that student does not qualify for an “IN” grade. Also if the student does not have a passing a grade when the first two exams are averaged, then that student does not qualify for an “IN” grade. This is an FIU rule – and all professors have to abide by it. We have to fill out a form and provide the documentation before any ”IN” grade can be entered.

5. If you missed the first test in the semester for an allowable, legitimate, verifiable reason you may be able to take a make-up exam as long as you provide adequate documentation and notify the professor at within two hours of the scheduled exam time. You must take the make-up test on the first opportunity you get to return to school. The allowable reasons are restricted to medical emergencies, traffic accidents in which your car becomes non-functional on your way to the exam, and deaths in the immediate family (parents, siblings, or children). We are not allowed to give make-up tests for work related issues. As always you must provide documentation. If you’re exempted from the 2nd exam, you will not get a make-up; your other scores will instead be used (with their corresponding weights) to produce your final grade – but in this case, please remember that you won’t qualify for an IN grade.

6. So please go & seek whatever medical treatment you may need- and get the necessary documentation - instead of telling the professor just a few minutes before the exam that you are unable to take it. Our hands are tied – we have to get documentation before we can give any make-up exam or exempt you from an exam. And if we give make-up exams or exemptions without documentation we can be fired and even be sued. If you have any questions about this matter, please contact the Math Division Director or the Math Undergraduate Program Director. Below are two useful links if you are not feeling well.

A. <https://studentaffairs.fiu.edu/health-and-fitness/student-health/>

B. <https://studentaffairs.fiu.edu/health-and-fitness/counseling-and-psychological-services/>

MAD 3512 - THEORY OF ALGORITHMS FLORIDA INT'L UNIV.

HOMEWORK SHEET SEVENTH EDITION

TEXTBOOK: An Introduction to Formal Languages and Automata

by Peter Linz, 7th Edition (D.C. Heath & Co., 2022)

The HW problems for the 7th edition. They are identical to those of the 6th edition.

Review of Discrete Math: There is no time for this section to be covered in class

Sec. 1.1 Nos. 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, 24,

31, 36, 37, 38, 39, 40, 41, 42, 43.

(Self revision. If you have trouble with these problems review your Discrete Math.)

FOR ANSWERS: See Prof. Ram's webpage http://faculty.fiu.edu/~ramsamuj/

Ch. 1 - Formal Languages and Regular Expressions:

Sec. 1.2 Nos. 1, 2, 3, 4, 5, 7, 8, 9, 10, 11.

Sec. 3.1 Nos. 1, 2, 5, 6, 7, 8, 9a-d, 10, 11, 12, 13, 14, 15, 19a-c, 20a-c, 21a-c, 22a-d.

Suppl. Prob. # E1, E2, E3, E4, E5 (available from Prof. Ram’s webpage).

Ch. 2 - Context-Free & Right Linear Grammars:

Sec. 1.2 Nos. 12, 13, 14a-d, 15, 16, 17a-h, 18a-d, 19, 20, 18a-c, 22, 23, 24.

Sec. 3.3 Nos. 3, 4, 5a-b, 6, 7, 11, 12.

Sec. 5.1 Nos. 3, 9a-d, 12a-d, 16a-b, 23, 24, 25, 26, 27.

Sec. 5.2 Nos. 2, 3, 4, 7, 8, 13, 15, 17

Ch. 3 - Finite Automata (Deterministic and Non-Deterministic):

Sec. 2.1 Nos. 1, 4a-d, 7a-d, 9, 10, 11a-c, 12, 13, 14, 15

Sec. 2.2 Nos. 3, 4, 5, 6, 8, 9, 12, 13, 15, 17

Sec. 2.3 Nos. 1, 3, 7, 8, 9a-b, 12, 13a-b

Sec. 2.4 Nos. 2, 4, 6

Ch. 4 - Regular and Non-regular Languages :

Sec. 3.2 Nos. 3, 4a-b, 5, 6, 7a, 9, 10a-b, 11, 12, 15a, 18a-b

Sec. 3.3 Nos. 1, 3, 4, 5, 6, 7 11, 12, 13, 14

Sec. 4.1 Nos. 9, 10, 11, 16, 17, 18, 20, 27

Sec. 4.2 Nos. 2, 3, 5, 7

Sec. 4.3 Nos. 4 a-b, 5 a-f, 6 a-d, 17, 18, 24, 26, 27

Suppl. Prob. Nos. E6, E7, E8, E9, E10, E11 (from Prof. Ram’s webpage)

Ch. 5 - Turing Machines, Turing-Computable Functions & Turing-Decidable relations:

Sec. 9.1 Nos. 3, 4, 5, 6, 7, 8a,b,g, 10, 13

Sec. 11.1 Nos. 2, 5, 6, 7, 8

Ch. 6 - Recursive Functions, Recursive & Semi-recursive relations, Comp. Complexity

Sec. 13.1 Nos. 1a-b, 4, 5a-b, 7a-b, 8, 10, 12a-c, 13a-b, 14, 18a-d

Suppl. Prob. Nos. E12, E13, E14 (available from Prof. Ram’s webpage)

Sec. 14.1 Nos. 1, 2, 3 (End of 7th ed. HW)

MAD 3512 - THEORY OF ALGORITHMS FLORIDA INT'L UNIV.

HOMEWORK SHEET SIXTH EDITION

TEXTBOOK: An Introduction to Formal Languages and Automata

by Peter Linz, 6th Edition (D.C. Heath & Co., 2017)

Review of Discrete Math: There is no time for this section to be covered in class

Sec. 1.1 Nos. 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, 24,

31, 36, 37, 38, 39, 40, 41, 42, 43.

(Self revision. If you have trouble with these problems review your Discrete Math.)

FOR ANSWERS: See Prof. Ram's webpage http://faculty.fiu.edu/~ramsamuj/

Ch. 1 - Formal Languages and Regular Expressions:

Sec. 1.2 Nos. 1, 2, 3, 4, 5, 7, 8, 9, 10, 11.

Sec. 3.1 Nos. 1, 2, 5, 6, 7, 8, 9a-d, 10, 11, 12, 13, 14, 15, 19a-c, 20a-c, 21a-c, 22a-d.

Suppl. Prob. # E1, E2, E3, E4, E5 (available from Prof. Ram’s webpage).

Ch. 2 - Context-Free & Right Linear Grammars:

Sec. 1.2 Nos. 12, 13, 14a-d, 15, 16, 17a-h, 18a-d, 19, 20, 18a-c, 22, 23, 24.

Sec. 3.3 Nos. 3, 4, 5a-b, 6, 7, 11, 12.

Sec. 5.1 Nos. 3, 9a-d, 12a-d, 16a-b, 23, 24, 25, 26, 27.

Sec. 5.2 Nos. 2, 3, 4, 7, 8, 13, 15, 17

Ch. 3 - Finite Automata (Deterministic and Non-Deterministic):

Sec. 2.1 Nos. 1, 4a-d, 7a-d, 9, 10, 11a-c, 12, 13, 14, 15

Sec. 2.2 Nos. 3, 4, 5, 6, 8, 9, 12, 13, 15, 17

Sec. 2.3 Nos. 1, 3, 7, 8, 9a-b, 12, 13a-b

Sec. 2.4 Nos. 2, 4, 6

Ch. 4 - Regular and Non-regular Languages :

Sec. 3.2 Nos. 3, 4a-b, 5, 6, 7a, 9, 10a-b, 11, 12, 15a, 18a-b

Sec. 3.3 Nos. 1, 3, 4, 5, 6, 7 11, 12, 13, 14

Sec. 4.1 Nos. 9, 10, 11, 16, 17, 18, 20, 27

Sec. 4.2 Nos. 2, 3, 5, 7

Sec. 4.3 Nos. 4 a-b, 5 a-f, 6 a-d, 17, 18, 24, 26, 27

Suppl. Prob. Nos. E6, E7, E8, E9, E10, E11 (from Prof. Ram’s webpage)

Ch. 5 - Turing Machines, Turing-Computable Functions & Turing-Decidable relations:

Sec. 9.1 Nos. 3, 4, 5, 6, 7, 8a,b,g, 10, 13

Sec. 11.1 Nos. 2, 5, 6, 7, 8

Ch. 6 - Recursive Functions, Recursive & Semi-recursive relations, Comp. Complexity

Sec. 13.1 Nos. 1a-b, 4, 5a-b, 7a-b, 8, 10, 12a-c, 13a-b, 14, 18a-d

Suppl. Prob. Nos. E12, E13, E14 (available from Prof. Ram’s webpage)

Sec. 14.1 Nos. 1, 2, 3 (End of 6th ed. HW)

MAD 3512 - THEORY OF ALGORITHMS FLORIDA INTERNATIONAL UNIV.

REVISION FOR TEST #1 REMEMBER TO BRING AN 8x11 BLUE EXAM BOOKLET

KEY CONCEPTS & MAIN DEFINITIONS:

Alphabets, strings of letters, empty string λ, reverse of a string, concatenation of strings, languages (sets of strings), **regular expression** (REX**),** L(E) **= language described** by E**,** equivalent regular expressions**, regular languages; phrase-structured, context-free, linear & right-linear grammars; context-free, linear & right-linear languages; useless, unreachable, non-terminating, unit & lambda productions**; normal forms for CFGs and RLGs, parsing and parsing algorithms, derivations, generating tree of a grammar, L(G**) = language generated** by G**,** equivalent grammars, derivation tree, **leftmost derivations**, **ambiguous grammars, inherently ambiguous languages,** finite state machines (finite automata), deterministic finite acceptors (DFAs), transition table, transition graph, **transition function** & **extended transition function** forDFAs, L(M) = **language accepted** by M**, inaccessible states** in a DFA**, indistinguishable (redundant)** states in a DFA**, reduced (minimal)** DFA, non-deterministic finite acceptors (NFAs), **transition relation** & **extended transition relation** of NFAs, lambda transitions, crashing in NFAs, equivalent NFAs & DFAs**,** **reaching set** of a string ψ.

MAIN PROBLEM SOLVING TECHNIQUES:

1. How to prove or disprove properties of strings involving reverse & concatenations.

2. How to prove or disprove subset relations or equality between languages

3. How to find a regular expression which describes a language & how to find the lang. described by a regular expression.

4. How to find a CFG or RLG which generates a given language L and how to find the language generated by a CFG or RLG G.

5. How to find a derivation tree for a given string ψ in a CFG G and how to tell if ψ has two or more leftmost derivations in G.

6. How to find a DFA or NFA which accepts a given language L and how to find the language accepted by a DFA or NFA M.

7. How to partition the states of a DFA into blocks of indistinguishable states and how to find the minimal DFA.

8. How to convert a given NFA, M, into an equivalent DFA MD .

9. How to find the complement of a DFA, MD or an NFA, M .

MAIN THEOREMS:

1. Any language based on a finite (or countable) alphabet V is countable.

2. The set of all languages based on the alphabet V is uncountable.

3. The sets of all finite, regular, context-free, or phrase-structured languages are all countable.

4. Any CFG or RLG is equivalent to one in normal form.

5. Any DFA can be reduced to one with no redundant or inaccessible states.

6. Any NFA can be converted into an equivalent DFA.

MAD 3512 - THEORY OF ALGORITHMS FLORIDA INTERNATIONAL UNIV.

REVISION FOR TEST #2 REMEMBER TO BRING AN 8x11 BLUE EXAM BOOKLET

KEY CONCEPTS AND MAIN DEFINITIONS:

**Complement of a DFA, reaching sets, back-tracking sets**, the complements & the reverse of a language, (LC )R and (LR )C, ambiguity in RLGs, generalized finite automata (GFA); equivalent acceptors, grammars, & regular expressions; **closure properties, homomorphisms, decidability properties**, regular and non-regular languages, **the pumping lemma for regular languages,** counter-examples involving non-regular languages, Turing machines, **configuration, computation**, deterministic TMs, **Turing-computable functions, Turing-recognizable (acceptable) languages, Turing-decidable languages, Turing semi-decidable & Turing-decidable relations**, Universal TMs, **the Halting Problem, the Busy-beaver function, primitive recursive functions, the initial functions, composition, primitive recursion, total and partial functions, minimization, recursive functions; recursive, semi-recursive & r.e. relations; recursive, semi-recursive & r.e. languages,** phrase-structured grammars & languages (PSG & PSL), (r.e. = recursively enumerable),

------ Computational complexity, Time complexity, Space complexity, Deterministic & Non-deterministic algorithms, P-type problems, NP-type problems, Intractable problems, the P=NP problem.

MAIN PROBLEM SOLVING TECHNIQUES:

1. How to convert RLGs into NFAs and how to convert NFAs into RLGs.

2. How to constructing an OAS-NFA equivalent to a regular expression and how to find a regular expression that describes the language accepted by an NFA.

3. How to detect & remove ambiguity in a right linear grammar.

4. Given an NFA M, how to find an NFAs which accept L(M)C and L(M)R.

5. How to prove closure & decidability properties of regular languages.

6. How to prove that L is non-regular from first principles & by using previously proved results.

7. How to prove or disprove certain closure properties of regular and non-regular languages.

8. Finding the language accepted or function computed by a TM.

9. How to verify that a function is primitive recursive by using prim. rec. and compositions.

10. How to verify that a function is recursive by using minimization, prim. rec. & composition.

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11\*. How to prove the closure properties of recursive relations under intersection, union & compl.

12\*. How to estimate the complexity of an algorithm.

MAIN THEOREMS:

1. Main Theorem on regular languages (LDFA = LNFA = LRLG = LREX).

2. The Closure Theorem and Decidability Theorem for regular languages.

3. The Pumping Lemma for regular languages.

4. The Halting Problem is not Turing-decidable.

5. The busy-beaver function is not Turing-computable.

6. The function f is Turing-computable if and only if f is a recursive function.

7. The relation R is Turing-decidable if and only if R is a recursive relation.

8. The language L is Turing-recognizable iff L is r.e. iff L is a PSL.