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Type of assessment:	**Individual**
Coursework Title:	CW1.1
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Date: *09/02/24*

Part I: Regexes & Grammars

Submission: On Canvas, under Assignments
Deadline: Week 5, Mon 12th Feb 2023
Marks possible: 28 (7% of your final mark)

Notes on answering this question:

- Regexes are enclosed within, / /, e.g. /ab+/
- Pay attention to what kind of grammar I ask for (*regular*, or *context free*, or some other type).
- For instance: if I ask for a **regular** grammar and you give me some other kind of grammar, then you may lose marks!
- In particular, if your regular grammar contains a rule of the form $S \longrightarrow abγ$ or $S \longrightarrow D$ or $S \longrightarrow \varepsilon D$, then this is not a regular grammar and your answer contains an error.
- Always clearly specify the start symbol.
- The alphabet (set of tokens) of a language cannot contain ε. ε is the empty string, that is, an absence of tokens. If your answer contains something of the form T={ε,…} (where T is supposed to be a set of tokens for your language) — then your answer is probably wrong and you're probably losing marks.

Some of you have not met set notation before, so here's a quick tutorial:
- The language determined by the regex /a*/ is { a^n | n ∈ {0,1,2,…} } or equivalently { a^n | n ≥ 0 }.
- The language determined by the regex /(a|b)?/ is { a, b, ε }.
- The language determined by the regex /a+b+/ is { $a^m b^n$ | m,n ≥ 1 } or equivalently { $a^m b^n$ | m ≥ 1, n ≥ 1 } or equivalently { $a^m b^n$ | m,n ∈ {1,2,3,…} }.
- The language determined by the English description "any nonzero digit" is { 1, 2, 3, 4, 5, 6, 7, 8, 9} or equivalently { 1, 2, … , 9} or equivalently { n | 9 ≥ n ≥ 1 } or equivalently { n | 0 < n ≤ 9 }.
- When I say "Give/Write the language …", avoid informal descriptions in English as this is often ambiguous: I expect you to use the same set theoretic notation.

1. Write a regex to identify dates of the form dd/mm/yyyy or dd.mm.yyyy, but *not* using mixed separators such as dd/mm.yyyy. *[1 mark]*

((0[1-9]|[1-2][0-9]|3[0-1])\/(0[1-9]|1[0-2])\/[0-9][0-9][0-9][0-9])|((0[1-9]|[1-2][0-9]|3[0-1])\.(0[1-9]|1[0-2])\.[0-9][0-9][0-9][0-9])

2. Write a regex for the set of even numbers without leading zeroes (base 10; so the alphabet is `[0-9]`). Note that 0 and 2 and 10 and 20 are even numbers without leading zeroes, and 00 and 02 and 1 and 01 are not even numbers without leading zeroes. Check that your regex accepts 100 and 10012. *[2 marks]*

^([02468]|[1-9][0-9]*[02468])$

3. Which of the following matches regex /`[a-zA-Z]*[^,]=`/ ? *[1 mark]*

a) `Butt=` Matches
b) `BotHEr,=` Does not Match
c) `Ample` Does not Match
d) `FIdDlE7h=` Does not Match
e) `Brittle =` Matches
f) `Other.=` Matches

4. Write the language determined by the regex /`a*b*`/ *[1 mark]*

L = {$a^p b^q$ | p≥0, q≥0}

5. Write a **regular** grammar to generate the language determined by the regex /`a*b*`/ *[2 marks]*

S ::= aS | aT | T | ε
T ::= b | bT | ε

6. Write a regular grammar to generate the language matched by /`Whiske?y`/ *[2 marks]*

S ::= WA (where "W" is terminal)
A ::= hB
B ::= iC
C ::= sD
D ::= kE
E ::= eF | F
F ::= y

7. Write a regular grammar to generate decimal numbers; the relevant regex is /`[1-9][0-9]*(\.[0-9]*[1-9])?`/.
You may find it useful to use notation resembling D ::= 0 | 1 | … | 9 to denote an set of ten production rules. *[3 marks]*

S ::= 1|2|...|9|1A|2A|...|9A|1B|2B|...|9B
A ::= 0|1|...|9|0A|1A|...|9A|0B|1B|...|9B
B ::= .C
C ::= 0C|1C|...|9C|D
D ::= 0|1|...|9

8. Give a **context free** grammar for the language $L=\{0^n1^m0^m1^n \mid n,m \in \mathbb{N}\}$ *[2 marks]*

S::= 0S1 | 0A1
A::= 1A0 | 10

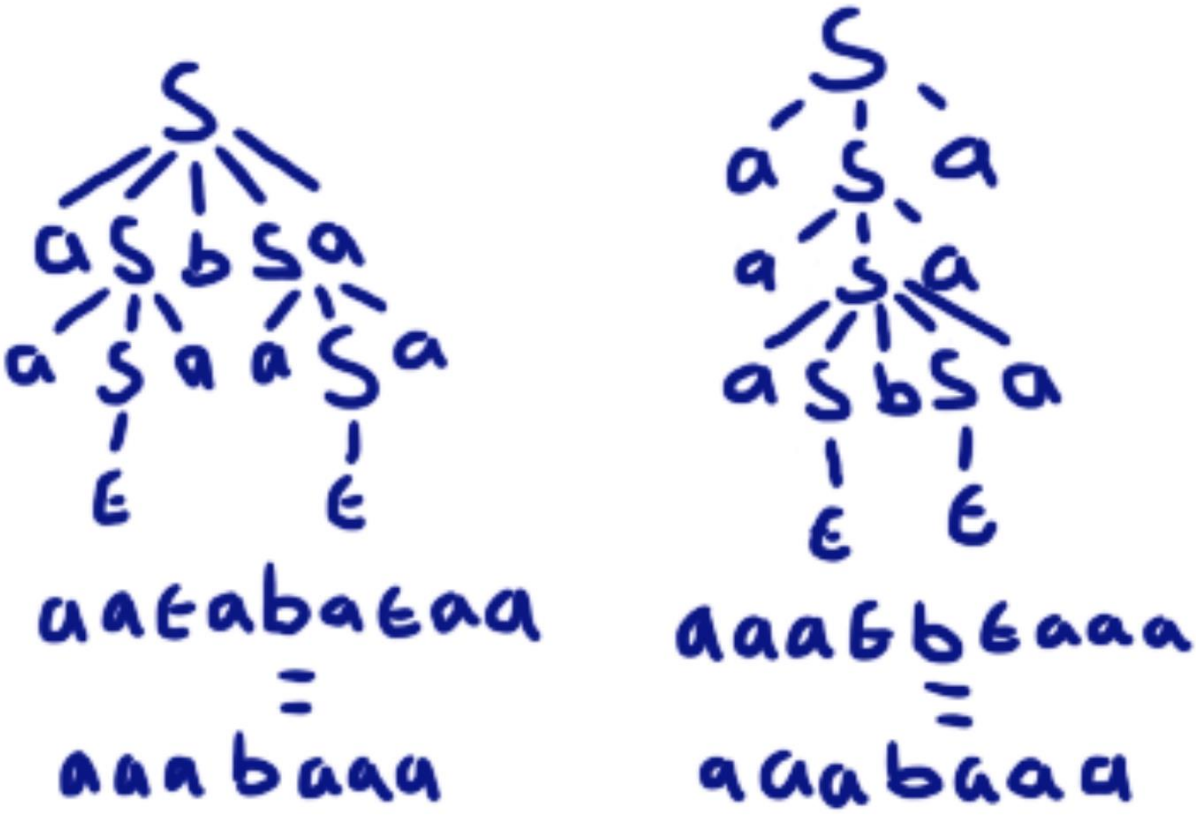
9. A parity-sequence is a sequence consisting of 0s and 1s that has an even number of ones. Give a grammar for parity-sequences. *[2 marks]*

S ::= 0S | 1A | 0
A ::= 0A | 1S | 1

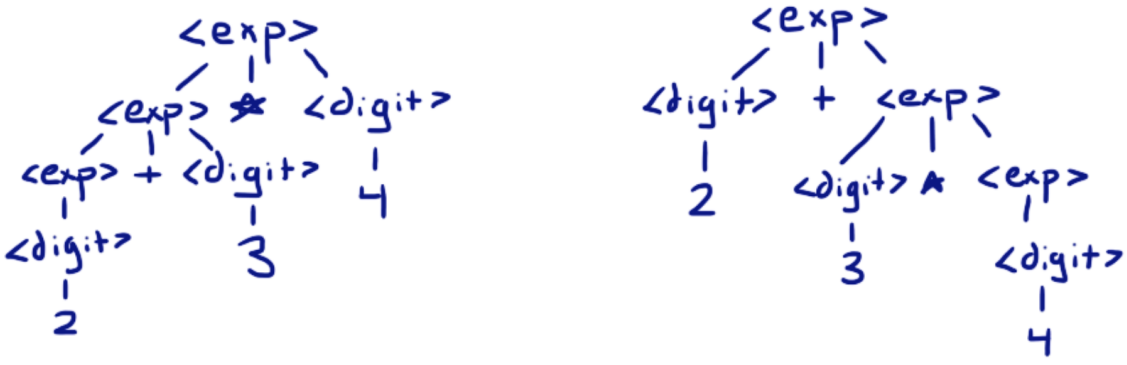
10. Construct context-free grammars that generate the following languages: *[7 marks]*

a. $(ab|ba)^*$
   S ::= ε | abS | ab | baS | ba
b. $\{(ab)^n a^n \mid n\geq 1\}$
   S ::= abAa
   A ::= abAa | ε
c. $\{w\in\{a,b\}^* \mid$ w contains exactly two bs and any number of as $\}$
   S ::= aS | bA
   A ::= aA | bB
   B ::= aB | ε
d. $\{a^n b^m \mid 0\leq n\leq m\leq 2n\}$
   S ::= A | ε
   A ::= aB | aBB
   B ::= b | Ab

11. Prove that the following grammar is ambiguous. *[3 marks]*
   a. $G=(\{S\},\{a,b\},P,S)$ with productions: $S \longrightarrow aSa \mid aSbSa \mid \varepsilon$



12. Write / Draw two distinct parse trees for $2+3*4$ and explain, in intuitive terms, the meaning of the two different parses to their denotation. *[2 marks]*



In the left tree, 2 and 3 are added together first, before being multiplied by 4, leading to the final number of 20.

In the right tree, 3 and 4 are multiplied first, before having 2 added to the product, leading to the final number of 14.

This is due to the ambiguous nature of the grammar that made $2+3*4$, and why two trees that are derived from the same expression can be entirely different and lead to entirely different products.