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Homework Assignment Submitted Successfully.

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Number of questions:	25
Positive points per question:	4.0
Negative points per question:	0.0
Your score:	100

1. Let L be the language of all strings of a's and b's such that no prefix (proper or not) has more b's than a's. Let G be the grammar with productions

```
S → aS | aSbS | ε
```

To prove that L = L(G), we need to show two things:

1. If S =>* w, then w is in L.
2. If w is in L, then S =>* w.

We shall consider only the proof of (1) here. The proof is an induction on n, the number of steps in the derivation S =>* w. Here is an outline of the proof, with reasons omitted. You need to supply the reasons.

Basis:

1) If n=1, then w is ε because _______.

2) w is in L because _______.

Induction:

3) Either (a) S => aS $=>^{n-1}$ w or (b) S => aSbS $=>^{n-1}$ w because _______.

4a) In case (a), w = ax, and S $=>^{n-1}$ x because _______.

5a) In case (a), x is in L because _______.

6a) In case (a), w is in L because _______.

4b) In case (b), w can be written w = aybz, where S $=>^{p}$ y and S $=>^{q}$ z for some p and q less than n because _______.

5b) In case (b), y is in L because _______.

6b) In case (b), z is in L because _______.

7b) In case (b), w is in L because _______.

For which of the steps above the appropriate reason is contained in the following argument:
"All n-step derivations of w produce either ε (for n=1) or use one of the productions with at least one nonterminal in the body (for n > 1). In case the production S → aS is used, then w=ax with x being

produced by a (n-1)-step derivation. In case the production S → aSbS is used then w=aybz with y and z being produced by derivations with number of steps less than n."

a) 6a
b) 6b
c) 7b
d) 3

Answer submitted: **d)**

You have answered the question correctly.

2. Let G be the grammar:

```
S → SS | (S) | ε
```

L(G) is the language BP of all strings of balanced parentheses, that is, those strings that could appear in a well-formed arithmetic expression. We want to prove that L(G) = BP, which requires two inductive proofs:

1. If w is in L(G), then w is in BP.
2. If w is in BP, then w is in L(G).

We shall here prove only the second. You will see below a sequence of steps in the proof, each with a reason left out. These reasons belong to one of three classes:

A) Use of the inductive hypothesis.

B) Reasoning about properties of grammars, e.g., that every derivation has at least one step.

C) Reasoning about properties of strings, e.g., that every string is longer than any of its proper substrings.

The proof is an induction on the length of w. You should decide on the reason for each step in the proof below, and then identify from the available choices a correct pair consisting of a step and a kind of reason (A, B, or C).

Basis: Length = 0.

(1) The only string of length 0 in BP is ε because ________

(2) ε is in L(G) because ________

Induction: |w| = n > 0.

(3) w is of the form (x)y, where (x) is the shortest proper prefix of w that is in BP, and y is the remainder of w because ________

(4) x is in BP because ________

(5) y is in BP because ________

(6) |x| < n because ________

(7) |y| < n because ________

(8) x is in L(G) because ________

(9) y is in L(G) because ________

(10) (x) is in L(G) because ________

(11) w is in L(G) because ________

a) (10) for reason A
b) (6) for reason C
c) (2) for reason A
d) (8) for reason C

Answer submitted: **b)**

You have answered the question correctly.

3. Consider the following identities for regular expressions; some are false and some are true. You are asked to decide which and in case it is false to provide the correct counterexample.

(a) R(S+T)=RS+RT
(b) (R*)*=R*
(c) (R*S*)*=(R+S)*
(d) (R+S)*=R*+S*
(e) S(RS+S)*R=RR*S(RR*S)*
(f) (RS+R)*R=R(SR+R)*

a) (c) is false and a counterexample is: R={ab},T={b}, S={b}

b) (e) is true

c) (e) is false and a counterexample is: R={a},T={a}, S={b}

d) (b) is false and a counterexample is: R={ab},T={a}, S={b}

Answer submitted: **c)**

You have answered the question correctly.

4. Here is the transition function of a simple, deterministic automaton with start state A and accepting state B:

	0	**1**
A	A	B
B	B	A

We want to show that this automaton accepts exactly those strings with an odd number of 1's, or more formally:

$\delta(A,w) = B$ if and only if w has an odd number of 1's.

Here, δ is the extended transition function of the automaton; that is, $\delta(A,w)$ is the state that the automaton is in after processing input string w. The proof of the statement above is an induction on the length of w. Below, we give the proof with reasons missing. You must give a reason for each step, and then demonstrate your understanding of the proof by classifying your reasons into the following three categories:

A)
Use of the inductive hypothesis.

B)
Reasoning about properties of deterministic finite automata, e.g., that if string s = yz, then $\delta(q,s) = \delta(\delta(q,y),z)$.

C)
Reasoning about properties of binary strings (strings of 0's and 1's), e.g., that every string is longer than any of its proper substrings.

Basis ($|w| = 0$):

(1)
$w = \varepsilon$ because ________

(2)
$\delta(A,\varepsilon) = A$ because ________

(3)
ε has an even number of 0's because ________

Induction ($|w| = n > 0$)

(4)
There are two cases: (a) when w = x1 and (b) when w = x0 because ________
Case (a):

(5)
In case (a), w has an odd number of 1's if and only if x has an even number of 1's because ________

(6)
In case (a), $\delta(A,x) = A$ if and only if w has an odd number of 1's because ________

(7)
In case (a), $\delta(A,w) = B$ if and only if w has an odd number of 1's because ________
Case (b):

(8)
In case (b), w has an odd number of 1's if and only if x has an odd number of 1's because ________

(9)
In case (b), $\delta(A,x) = B$ if and only if w has an odd number of 1's because ________

(10)
In case (b), $\delta(A,w) = B$ if and only if w has an odd number of 1's because ________

a) (6) for reason A.
b) (3) for reason B.
c) (9) for reason C.
d) (8) for reason B.

Answer submitted: **a)**

You have answered the question correctly.

5. G_1 is a context-free grammar with start symbol S_1, and no other nonterminals whose name begins with "S." Similarly, G_2 is a context-free grammar with start symbol S_2, and no other nonterminals whose name begins with "S." S_1 and S_2 appear on the right side of no productions. Also, no nonterminal appears in both G_1 and G_2.

We wish to combine the symbols and productions of G_1 and G_2 to form a new grammar G, whose language is the union of the languages of G_1 and G_2. The start symbol of G will be S. All productions and symbols of G_1 and G_2 will be symbols and productions of G. Which of the following sets of productions, added to those of G, is guaranteed to make L(G) be $L(G_1)$ [union] $L(G_2)$?

a) $S \rightarrow S_3S_2,\ S_3 \rightarrow S_1$
b) $S \rightarrow S_1S_2 \mid S_2S_1$
c) $S \rightarrow S_1S_3 \mid S_2S_3,\ S_3 \rightarrow \varepsilon$
d) $S \rightarrow S_1,\ S_1 \rightarrow S_2,\ S_2 \rightarrow \varepsilon$

Answer submitted: **c)**

You have answered the question correctly.

6. Consider the following languages and grammars. G_1: $S \rightarrow aA|aS,\ A \rightarrow ab$
G_2: $S \rightarrow abS|aA,\ A \rightarrow a$
G_3: $S \rightarrow Sa|AB,\ A \rightarrow aA|a,\ B \rightarrow b$
G_4: $S \rightarrow aS|b$
L_1: $\{a^ib|\ i=1,2,...\}$
L_2: $\{(ab)^iaa|\ i=0,1,...\}$
L_3: $\{a^ib|\ i=2,3,...\}$
L_4: $\{a^iba^j|\ i=1,2,...,\ j=0,1,...\}$
L_5: $\{a^ib|\ i=0,1,...\}$

Match each grammar with the language it defines. Then, identify a correct match from the list below.

a) G_1 defines L_5.
b) G_2 defines L_1.
c) G_3 defines L_4.
d) G_3 defines L_1.

Answer submitted: **c)**

You have answered the question correctly.

7. Let *h* be the homomorphism defined by h(a) = 01, h(b) = 10, h(c) = 0, and h(d) = 1. If we take any string *w* in (0+1)*, $h^{-1}(w)$ contains some number of strings, N(w). For example, $h^{-1}(1100)$ = {ddcc, dbc}, i.e., N (1100) = 2. We can calculate the number of strings in $h^{-1}(w)$ by a recursion on the length of *w*. For example, if w = 00x for some string x, then N(w) = N(0x), since the first 0 in w can only be produced from *c*, not from *a*.

Complete the reasoning necessary to compute N(w) for any string *w* in (0+1)*. Then, choose the correct value of N(01100110).

a) 34

b) 8

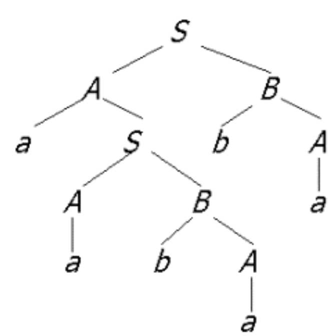
c) 128

d) 16

Answer submitted: **d)**

You have answered the question correctly.

8. The folowing is a parse tree in some unknown grammar G:



Which of the following productions is **definitely not** a production of G?

a) None of the other choices.

b) S → AB

c) S → aC

d) A → a

Answer submitted: **a)**

You have answered the question correctly.

9. Let L be the language of all strings of a's and b's such that no prefix (proper or not) has more b's than a's. Let G be the grammar with productions

```
S → aS | aSbS | ε
```

To prove that L = L(G), we need to show two things:

1. If S =>* w, then w is in L.
2. If w is in L, then S =>* w.

We shall consider only the proof of (1) here. The proof is an induction on n, the number of steps in the derivation S =>* w. Here is an outline of the proof, with reasons omitted. You need to supply the reasons.

Basis:

1)
If n=1, then w is ε because _______.
2)
w is in L because _______.
Induction:
3)
Either (a) $S \Rightarrow aS \Rightarrow^{n-1} w$ or (b) $S \Rightarrow aSbS \Rightarrow^{n-1} w$ because _______.
4a)
In case (a), w = ax, and $S \Rightarrow^{n-1} x$ because _______.
5a)
In case (a), x is in L because _______.
6a)
In case (a), w is in L because _______.
4b)
In case (b), w can be written w = aybz, where $S \Rightarrow^{p} y$ and $S \Rightarrow^{q} z$ for some p and q less than n because _______.
5b)
In case (b), y is in L because _______.
6b)
In case (b), z is in L because _______.
7b)
In case (b), w is in L because _______.

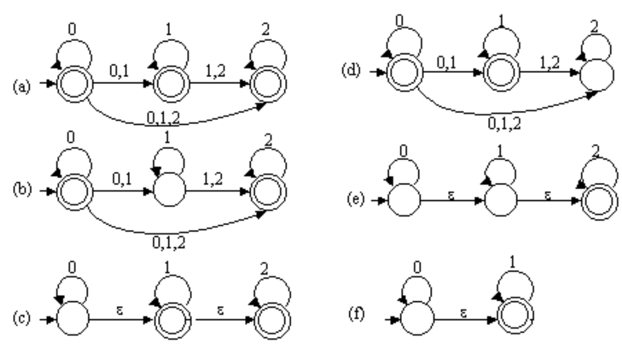
For which of the steps above the appropriate reason is contained in the following argument:
"The following two statements are true
(i) if string x has no prefix with more b's than a's, then neither does string ax,
(ii) if strings y and z are such that no prefix has more b's than a's, then neither does string aybz."

a) 5a
b) 3
c) 4a
d) 6a

Answer submitted: **d)**

You have answered the question correctly.

10. Identify which automata define the same language and provide the correct counterexample if they don't. Choose the correct statement from the list below.



a) (c) and (b) do not define the same language and the following counterexample shows it. String 0012 is accepted by one and not by the other.
b) (e) and (d) do not define the same language and the following counterexample shows it. String 01 is accepted by one and not by the other.
c) (b) and (f) do not define the same language and the following counterexample shows it. String 0012 is accepted by one and not by the other.
d) (a) and (e) do not define the same language and the following counterexample shows it. String 0012 is accepted by one and not by the other.

Answer submitted: **c)**

You have answered the question correctly.

11. Consider the grammar G1:

$S \to \varepsilon \mid aS \mid aSbS$

Which of the following is correct (for a choice to be correct, all propositions must be correct)?

a) a) G1 generates all and only the strings of a's and b's such that every prefix has at least as many a's as b's. b) The inductive hypothesis to prove it is: For n < k, it holds that: For any word in G1, any prefix of length n, is such that all its prefixes contain at least as many a's as b's.

b) The string aaba is not generated by the grammar.

c) a) G1 generates all and only the strings of a's and b's such that every prefix has at least as many a's as b's. b) The following inductive hypothesis will prove it: For n less than k, G1 generates all and only the strings of a's and b's of length n such that every prefix has at least as many a's as b's.

d) The string aaabbbababaabba is not generated by the grammar.

Answer submitted: **c)**

You have answered the question correctly.

12. Here are the transitions of a deterministic pushdown automaton. The start state is q_0, and *f* is the accepting state.

State-Symbol	a	b	ε
q_0-Z_0	(q_1,AAZ_0)	(q_2,BZ_0)	(f,ε)
q_1-A	(q_1,AAA)	(q_1,ε)	-
q_1-Z_0	-	-	(q_0,Z_0)
q_2-B	(q_3,ε)	(q_2,BB)	-
q_2-Z_0	-	-	(q_0,Z_0)
q_3-B	-	-	(q_2,ε)
q_3-Z_0	-	-	(q_1,AZ_0)

Describe informally what this PDA does. Then, identify below, the one input string that takes the PDA into state q_3 (with any stack).

a) babbabaa

b) bbaa

c) bbbaa

d) babbbaa

Answer submitted: **c)**

You have answered the question correctly.

13. Programming languages are often described using an extended form of context-free grammar, where square brackets are used to denote an optional construct. For example, A → B[C]D says that an *A* can be replaced by a *B* and a *D*, with an optional *C* between them. This notation does not allow us to describe anything but context-free languages, since an extended production can always be replaced by several conventional productions.

Suppose a grammar has the extended productions:

```
A → 0B[C10D]1EF0 | 0BC1[0D1E]F0
```

Convert this pair of extended productions to conventional productions. Identify, from the list below, the conventional productions that are equivalent to the extended productions above.

a) `A → 0BC10D1EF0 | 0B1EF0 | 0BC1F0 | 0BF0`

b) `A → 0BC10D1EF0 | 0BF0`

c) `A → 0BA`$_1$`F0`
`A`$_1$` → C10D | 0D1E`

d) `A → 0BA`$_1$`1EF0 | 0BC1A`$_2$`F0`
`A`$_1$` → C10D | ε`
`A`$_2$` → 0D1E | ε`

Answer submitted: **d)**

You have answered the question correctly.

14. Which of the following problems about a Turing Machine *M* does Rice's Theorem imply is undecidable?

a) Is there some input that causes *M* to halt after no more than 500 moves?

b) Does *M* ever move left when started with a blank tape?

c) Does *M* ever write the symbol 0 on its tape?

d) Does the language of *M* contain at least 10 strings?

Answer submitted: **d)**

You have answered the question correctly.

15. The Turing machine M has:

- States q and p; q is the start state.
- Tape symbols 0, 1, and B; 0 and 1 are input symbols, and B is the blank.
- The following next-move function:

State	Tape Symbol	Move
q	0	(q,0,R)
q	1	(p,0,R)
q	B	(q,B,R)
p	0	(q,0,L)
p	1	none (halt)
p	B	(q,0,L)

Simulate M on the input 1010110, and identify one of the ID's (instantaneous descriptions) of M from the list below.

a) 101q0110

b) 000q0110

c) 1010q110

d) 000000p0

Answer submitted: **b)**

You have answered the question correctly.

16. Suppose we want to prove the statement S(n): "If $n \geq 2$, the sum of the integers 2 through n is (n+2)(n-1)/2" by induction on n. To prove the inductive step, we can make use of the fact that

$2+3+4+...+(n+1) = (2+3+4+...+n) + (n+1)$

Find, in the list below an equality that we may prove to conclude the inductive part.

a) If $n \geq 2$ then n + 1 + (n+2)(n-1)/2 = (n+3)(n)/2

b) If $n \geq 3$ then (n+2)(n-1)/2 + n + 1 = n(n+3)/2

c) If $n \geq 1$ then n + 1 + (n+2)(n-1)/2 = (n+3)(n)/2

d) If $n \geq 2$ then n(n+3))/2 + n + 1 = (n+2)(n-1)/2

Answer submitted: **a)**

You have answered the question correctly.

17. Here is the transition table of a DFA:

	0	1
→A	E	D
*B	A	C
C	G	B
D	E	A
*E	H	C
F	C	B
G	F	E
H	B	H

Find the minimum-state DFA equivalent to the above. Then, identify in the list below the pair of equivalent states (states that get merged in the minimization process).

a) A and F
b) D and H
c) A and G
d) G and H

Answer submitted: **b)**

You have answered the question correctly.

18. Which among the following languages is not regular (cannot be defined by a regular expression or finite automaton)?

a) $L=\{x \mid x=(a\, b^m c)^n$, n, m positive integers$\}$
b) $L=\{x \mid x=(a^2b^2c^2)^n$, n a positive integer$\}$
c) $L=\{x \mid x=a^m b^n c^k$, n, m, k positive integers$\}$
d) $L=\{x \mid x=a^m(bc)^n$, n, m positive integers$\}$

Answer submitted: **a)**

You have answered the question correctly.

19. Here is a context-free grammar:

```
S → AB | CD
A → BG | 0
B → AD | ε
C → CD | 1
D → BB | E
E → AF | B1
F → EG | 0C
G → AG | BD
```

Find all the nullable symbols (those that derive ε in one or more steps). Then, identify the true statement from the list below.

a) D is not nullable.
b) E is not nullable.
c) C is nullable.
d) G is not nullable.

Answer submitted: **b)**

You have answered the question correctly.

20. Consider the grammars:

G_1: S → AB, A → aAA|ε , B → abBB|ε
G_2:S → CB, C → aCC|aC|a, B → abBB|abB|ab
G_3:S → CB|C|B| ε , C → aCC|aC|a, B → abBB|abB|ab
G_4:S → ASB|ε, A → aA|ε, B → abB|ε
G_5:S → ASB|AB, A → aA|a, B → abB|ab
G_6:S → ASB|aab, A → aA|a, B → abB|ab

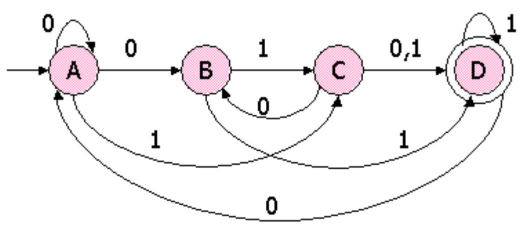
Describe the language of each of these grammars. Then, identify from the list below a pair of grammars that define the same language?

a) G_3 and G_2
b) G_2 and G_6
c) G_2 and G_5
d) G_5 and G_6

Answer submitted: **c)**

You have answered the question correctly.

21. Here is a nondeterministic finite automaton:



Convert this NFA to a DFA, using the "lazy" version of the subset construction described in Section 2.3.5 (p. 60), so only the accessible states are constructed. Which of the following sets of NFA states becomes a state of the DFA constructed in this manner?

a) {A,B,D}
b) The empty set
c) {A,C}
d) {B,C,D}

Answer submitted: **a)**

You have answered the question correctly.

22. Suppose one transition rule of some PDA P is δ(q,0,X) = {(p,YZ), (r,XY)}. If we convert PDA P to an equivalent context-free grammar G in the manner described in Section 6.3.2 (p. 247), which of the following could be a production of G derived from this transition rule? You may assume *s* and *t* are states of P, as well as *p, q*, and *r*.

a) [qXs] → 0[rXt][pYs]
b) [qXs] → 0[qYt][tZp]
c) [qXs] → 0[rXt][tYs]
d) [qXs] → [rXt][tYs]

Answer submitted: **c)**

You have answered the question correctly.

23.

Find, in the list below, a regular expression whose language is the reversal of the language of this regular expression: 1*23*. Recall that the reversal of a language is formed by reversing all its strings, and the reversal of a string $a_1a_2...a_n$ is $a_n...a_2a_1$.

a) 1*3*2
b) 3*1*2
c) 3*21*
d) 21*3*

Answer submitted: **c)**

You have answered the question correctly.

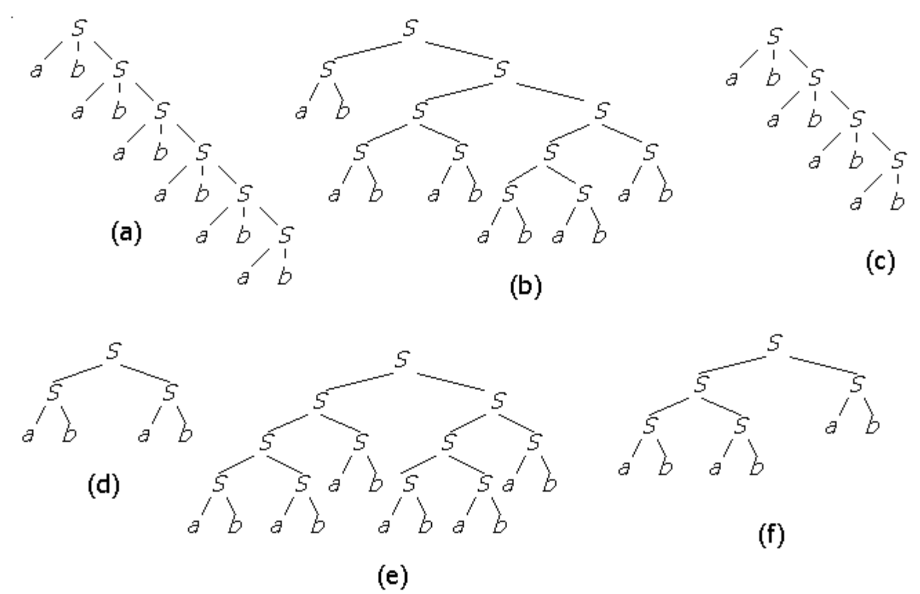
24. The language of regular expression (0+10)* is the set of all strings of 0's and 1's such that every 1 is immediately followed by a 0. Describe the complement of this language (with respect to the alphabet {0,1}) and identify in the list below the regular expression whose language is the complement of L((0+10)*).

a) (0+1)*(1+11)(0+1)*
b) 0*11(0+1)* + (0+1)*1
c) (0+1)*1(ε+1(0+1)*)
d) (0+10)*11(0+10)*

Answer submitted: **c)**

You have answered the question correctly.

25. Consider the grammar G: S → SS, S → ab. Which of the following strings is a word of L(G) AND is the yield of one of the parse trees for grammar G in the figure below?



a) ab
b) SababSabS
c) abababababab
d) ababSabab

Answer submitted: **c)**

You have answered the question correctly.