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Based on Section 7.1 of HMU.

1. 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, and then use the construction from Section 7.1.3 (p. 265) to modify the grammar's productions so there are no ε-productions. The language of the grammar should change only in that ε will no longer be in the language.

a) D → BB | E | B | ε

b) B → AD | A | D | ε

c) C → CD | C

d) C → CD | 1 | C

Answer submitted: **d)**

You have answered the question correctly.

Question Explanation:

S, A, B, D, and G are nullable. Thus, whenever one or more of these appear in a production body, we must add new bodies that have all subsets of the nullable symbols deleted. However, when the entire body consists of nullable symbols, we do not introduce the body ε. Finally, we eliminate all existing ε-productions; in this example, the only one is B → ε. The result:

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

2. For the grammar:

```
S → AB | CD
A → BC | a
B → AC | C
C → AB | CD
D → AC | d
```

1. Find the generating symbols. Recall, a grammar symbol is *generating* if there is a deriviation of at least one terminal string, starting with that symbol.
2. Eliminate all *useless productions* --- those that contain at least one symbol that is not a generating symbol.
3. In the resulting grammar, eliminate all symbols that are not *reachable* --- they appear in no string derived from S.

In the list below, you will find several statements about which symbols are generating, which are reachable, and which productions are useless. Select the one that is FALSE.

a) D → *d* is not useless.

b) D → AC is useless.

c) C is not generating.

d) *a* is not generating.

Answer submitted: **c)**

Your answer is incorrect.

To be generating, a nonterminal has to derive some terminal string. What terminal string can C generate? An algorithm for finding generating symbols is in Section 7.1.2 (p. 264).

Question Explanation:

All terminals are generating. The nonterminals A and D evidently derive terminal strings *a* and *d*, respectively. However, B and C are not generating. To see why, notice that each production for B and C has either B or C in the body. Then, since B and C are not generating, and each production for S has a B or C in the body, S is not generating.

Consequently, the only productions that are useful (not useless) are A → a and D → d. Therefore, the only symbol reachable from S is S itself.

The correct choice is: **d)**

3. A *unit pair* (X,Y) for a context-free grammar is a pair where:

1. X and Y are variables (nonterminals) of the grammar.
2. There is a derivation X =>* Y that uses only unit productions (productions with a body that consists of exactly one occurrence of some variable, and nothing else).

For the following grammar:

```
S → A | B | 2
A → C0 | D
B → C1 | E
C → D | E | 3
D → E0 | S
E → D1 | S
```

Identify all the unit pairs. Then, select from the list below the pair that is NOT a unit pair.

a) (B,C)

b) (C,A)

c) (C,D)

d) (S,S)

Answer submitted: **a)**

You have answered the question correctly.

Question Explanation:

The cycle of unit-productions S → A → D → S says that any pair involving only S, A, and D is a unit pair. Similarly, the cycle S → B → E → S tells us that any pair involving S, B, and E is a unit pair. But since S is on both cycles, there are derivations involving only unit productions from any of S, A, B, D, and E to any of these five variables. Thus, any combination of these five variables is a unit pair.

Further, the productions C → D | E tells us that any pair (C,X) is a unit pair if X is any of the six variables. The only pairs that are not unit pairs are (X,C) for X = S, A, B, D, or E.

4. Suppose we execute the Chomsky-normal-form conversion algorithm of Section 7.1.5 (p. 272). Let A → BC0DE be one of the productions of the given grammar, which has already been freed of ε-productions and unit productions. Suppose that in our construction, we introduce new variable X_a to derive a terminal *a*, and when we need to split the right side of a production, we use new variables Y_1, Y_2,...

What productions would replace A → BC0DE? Identify one of these replacing productions from the list below.

a) $A \rightarrow Y_1B$

b) $A \rightarrow BY_2$

c) $Y_3 \rightarrow DY_4$

d) $Y_1 \rightarrow CY_2$

Answer submitted: **d)**

You have answered the question correctly.

Question Explanation:

First, we introduce the production $X_0 \rightarrow 0$ for the terminal 0, and replace the given production by $A \rightarrow BCX_0DE$. Then, since the body has length 5, we introduce 5-2 = 3 new variables, Y_1, Y_2, and Y_3, with the productions:

$A \rightarrow BY_1$
$Y_1 \rightarrow CY_2$
$Y_2 \rightarrow X_0Y_3$
$Y_3 \rightarrow DE$

5. Convert the grammar:

```
S → A | B | 2
A → C0 | D
B → C1 | E
C → D | E | 3
D → E0 | S
E → D1 | S
```

to an equivalent grammar with no unit productions, using the construction of Section 7.1.4 (p. 268). Then, choose one of the productions of the new grammar from the list below.

a) $S \rightarrow E1$

b) $E \rightarrow 3$

c) $A \rightarrow C1$

d) $S \rightarrow E$

Answer submitted: **c)**

You have answered the question correctly.

Question Explanation:

Each of S, A, B, D, and E derives each of the others on this list, using only unit productions. Thus, they each get all the nonunit right sides of any of these. For example,

```
S → C0| C1 | E0 | D1 | 2
```

The variables A, B, D, and E have exactly the same five production bodies.

Variable C is a little different, since it derives each of the five other variables by unit

Variable C is a little different, since it derives each of the five other variables by unit productions. It therefore gets its own nonunit production body, 3, as well as the nonunit bodies of the others. That is:

```
C → C0| C1 | E0 | D1 | 2 | 3
```

6. 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) E is not nullable.

b) B is not nullable.

c) D is not nullable.

d) G is not nullable.

Answer submitted: **a)**

You have answered the question correctly.

Question Explanation:

B derives ε directly. Then, D derives ε using the production D → BB. Thus, B and D are nullable. We can then discover G is nullable because of the production G → BD; A is nullable by the production A → BG, and S is nullable by the production S → AB. But then we can discover no more nullable symbols. That is, C, E, and F are not nullable.

7. Here is a grammar, whose variables and terminals are NOT named using the usual convention. Any of *R* through *Z* could be either a variable or terminal; it is your

job to figure out which is which, and which could be the start symbol.

```
R → ST | UV
T → UV | W
V → XY | Z
X → YZ | T
```

We do have an important clue: There are no useless productions in this grammar; that is, each production is used in some derivation of some terminal string from the start symbol. Your job is to figure out which letters definitely represent variables, which definitely represent terminals, which could represent either a terminal or a nonterminal, and which could be the start symbol. Remember that the usual convention, which might imply that all these letters stand for either terminals or variables, does not apply here.

a) T could be a variable or a terminal.

b) V must be a terminal.

c) Y could be a variable or a terminal.

d) R must be the start symbol.

Answer submitted: **d)**

You have answered the question correctly.

Question Explanation:

All the symbols appearing on the left side of some production must be variables. Thus, R, T, V, and X are definitely variables. But if any other symbol was a variable, then it could not derive any terminal string, since it has no productions. Since all the other symbols appear in the body of some production, we can be sure they are terminals, because if they were variables they would render that production useless. Since we are told there are no useless productions, we can be sure S, U, W, Y, and Z are terminals.

We can also deduce that R is the start symbol. Notice that R appears in no production body. If R were not the start symbol, then its productions would be useless. Again, we are told there are no useless productions, so we must conclude R, and only R, could be the start symbol.