This exam consists of 22 questions. Each question has four options, exactly one of which is correct, while the other three options are incorrect. For each question, you can check multiple options.

I will grade each question in the following way. If you check none of the options, you get 0 points. If you check all four options, you get 0 points.

Check one option. If you check one option, and that option is correct, you get 2 points. If you check one option, and that option is wrong, you get −0.667 points (yes, negative!).

Check two options. If you check two options, and one of those options is correct, you get 1 point. If you check two options, and both of them are wrong, you get −1 point (yes, negative!).

Check three options. If you check three options, and one of those options is correct, you get 0.415 points. If you check three options, and all three of them are wrong, you get −1.245 points (yes, negative!).

The maximum point total is 22 × 2 = 44 points. I will calculate a percentage based on the points in the following way:

\[
\frac{\text{max}(0, \text{point total})}{44} \times 100
\]

Notice that if your point total is negative, you will get 0 percent
Example
Consider the grammar

\[
A ::= B \, y \mid y \, B \\
B ::= x \, C \, x \\
C ::= z \, A \mid \epsilon
\]

where \( \{A, B, C\} \) is the set of nonterminal symbols, \( A \) is the start symbol, \( \{x, y, z\} \) is the set of terminal symbols, and \( \epsilon \) denotes the empty string.

Question 1
Which nonterminals are nullable?

- [ ] A
- [ ] B
- [x] C
- [ ] A and B

Question 2
What is First(\( A \) )?

- [ ] \{y\}
- [x] \{x, y\}
- [ ] \{y, z\}
- [ ] \{x, y, z\}

Question 3
What is First(\( B \) )?

- [ ] \{\}
- [x] \{x\}
- [ ] \{x, z\}
- [ ] \{x, y, z\}

Question 4
What is First(\( C \) )?

- [ ] \{\}
- [x] \{z\}
- [ ] \{x, z\}
- [ ] \{y, z\}

Question 5
What is Follow(\( A \) )?

- [x] \{x\}
- [ ] \{y\}
- [ ] \{z\}
- [ ] \{x, y\}
Question 6
What is Follow(B)?

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>{x}</td>
<td>{y}</td>
<td>{z}</td>
<td>{x, y}</td>
</tr>
</tbody>
</table>

Question 7
What is Follow(C)?

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>{x}</td>
<td>{y}</td>
<td>{z}</td>
<td>{x, y}</td>
</tr>
</tbody>
</table>

Question 8
Is the grammar LL(1)?

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>Yes</td>
<td>No</td>
<td>The question cannot be answered with the information provided</td>
<td>The LL(1)-checker would go into an infinite loop</td>
</tr>
</tbody>
</table>

Example
Consider the grammar

\[
A ::= x C \mid B y \\
B ::= z A \mid \epsilon \\
C ::= z B x
\]

where \{A, B, C\} is the set of nonterminal symbols, A is the start symbol, \{x, y, z\} is the set of terminal symbols, and \(\epsilon\) denotes the empty string. The grammar is LL(1). The predictive parsing table is a two-dimensional table called \(\text{table}\).

Question 9
What does \(\text{table}(A, x)\) contain?

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>error</td>
<td>(\epsilon)</td>
<td>x C</td>
<td>B y</td>
</tr>
</tbody>
</table>

Question 10
What does \(\text{table}(A, y)\) contain?

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>error</td>
<td>(\epsilon)</td>
<td>x C</td>
<td>B y</td>
</tr>
</tbody>
</table>
Question 11
What does $\text{table}(A, z)$ contain?

3  $a$  error
   $b$  $\epsilon$
   $c$  $x \, C$
26  $d$  $B \, y$

Question 12
What does $\text{table}(B, x)$ contain?

5  $a$  error
23  $b$  $\times$
   $\epsilon$
   $c$  $z \, A$
   $d$  $z \, B \, x$

Question 13
What does $\text{table}(B, y)$ contain?

5  $a$  error
24  $b$  $\times$
   $\epsilon$
   $c$  $z \, A$
   $d$  $z \, B \, x$

Question 14
What does $\text{table}(B, z)$ contain?

$a$  error
27  $b$  $\times$
   $\epsilon$
   $c$  $z \, A$
   $d$  $z \, B \, x$

Question 15
What does $\text{table}(C, x)$ contain?

25  $a$  error
   $b$  $\epsilon$
   $c$  $z \, A$
   $d$  $z \, B \, x$

Question 16
What does $\text{table}(C, y)$ contain?

28  $a$  error
   $b$  $\epsilon$
   $c$  $z \, A$
   $d$  $z \, B \, x$
Question 17
What does \textit{table}(C, z) contain?

1 a error
b ε
1 c z A
27 d x z B x

Example
Consider the grammar

\[
A ::= C \; x \mid y \; B \\
B ::= x \; A \mid z \; B \\
C ::= z \mid \epsilon
\]

where \{A, B, C\} is the set of nonterminal symbols, A is the start symbol, \{x, y, z\} is the set of terminal symbols, and \(\epsilon\) denotes the empty string. The grammar is LL(1). Assume that a recursive-descent parser for the above grammar declares a variable \texttt{next} of type \texttt{token}, and that the program has three procedures \texttt{A()}, \texttt{B()}, \texttt{C()}, and the following main part:

\begin{verbatim}
void main() {
    next = getnexttoken();
    A();
}
\end{verbatim}

The procedure \texttt{getnexttoken()} gets the next token from an input file. Assume also we have the following helper procedure, written in pseudo-code:

\begin{verbatim}
void eat(token t) {
    if (t == next) {
        next = getnexttoken();
    }
    else {
        error();
    }
}
\end{verbatim}
Question 18
The procedure A() looks like:

```c
if (next == y) {
       eat(y);
       B()
}
else {
       ????
}
```

What is “????”?

- a /* do nothing */
- b error();
- c if ((next == x) or (next == z)) { C(); eat(x); } else { error(); }
- d if (next == z) { C(); eat(x); } else { error(); }

Question 19
The procedure B() looks like:

```c
if (next == x) {
       eat(x);
       A()
}
else {
       ????
}
```

What is “????”?

- a /* do nothing */
- b error
- c if ((next == y) or (next == z)) { eat(z); B(); } else { error(); }
- d if (next == z) { eat(z); B(); } else { error(); }

Question 20

The procedure C() looks like:

```c
if (next == z) {
    eat(z);
}
else {
    //
}
```

What is “????”?

- a /* do nothing */
- b error();
- c if (next == x) { /* do nothing */ } else { error(); }
- d if ((next == x) or (next == y)) { /* do nothing */ } else { error(); }

Example

Consider the grammar:

```
A ::= B x | y B
B ::= A x | y
```

where \{A, B\} is the set of nonterminal symbols, A is the start symbol, and \{x, y\} is the set of terminal symbols.
Question 21
Which grammar generates the same language as the above grammar?

$A ::= C \ D$
$C ::= \ y \ x \ | \ y \ A \ x \ | \ y \ y$
$D ::= \ x \ x \ D \ | \ \epsilon$

Example
Consider the grammar:

$A ::= x \ B \ | \ x \ y \ B$
$B ::= x \ A \ | \ \epsilon$

where \( \{A,B\} \) is the set of nonterminal symbols, \( A \) is the start symbol, \( \{x,y\} \) is the set of terminal symbols, and \( \epsilon \) denotes the empty string.
Question 22
Which grammar generates the same language as the above grammar?

29. $\text{a}$

$$
\begin{align*}
A & ::= x \ C \\
B & ::= x \ A \mid \varepsilon \\
C & ::= B \mid y \ B \\
\end{align*}
$$

30. $\text{b}$

$$
\begin{align*}
A & ::= x \ C \\
B & ::= x \ A \mid \varepsilon \\
C & ::= B \mid y \ A \\
\end{align*}
$$

31. $\text{c}$

$$
\begin{align*}
A & ::= x \ B \ C \\
B & ::= x \ A \mid \varepsilon \\
C & ::= B \mid y \ B \\
\end{align*}
$$

32. $\text{d}$

$$
\begin{align*}
A & ::= x \ B \ C \\
B & ::= x \ A \mid \varepsilon \\
C & ::= B \mid y \ A \\
\end{align*}
$$