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:

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

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

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

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 A
- b B
- c C
- d A and B

Question 2
What is First(\( A \))? 
- a \( \{y\} \)
- b \( \{x, y\} \)
- c \( \{y, z\} \)
- d \( \{x, y, z\} \)

Question 3
What is First(\( B \))? 
- a \( \{x\} \)
- b \( \{y\} \)
- c \( \{z\} \)
- d \( \{x, y\} \)

Question 4
What is First(\( C \))? 
- a \( \{x\} \)
- b \( \{y\} \)
- c \( \{z\} \)
- d \( \{x, y\} \)

Question 5
What is Follow(\( A \))? 
- a \( \{x\} \)
- b \( \{y\} \)
- c \( \{z\} \)
- d \( \{x, z\} \)
Question 6
What is Follow(B)?

a. \{x\}
b. \{y\}
c. \{z\}
d. \{x,z\}

Question 7
What is Follow(C)?

a. \{x\}
b. \{y\}
c. \{z\}
d. \{x,z\}

Question 8
Is the grammar LL(1)?

a. Yes
b. No
c. The question cannot be answered with the information provided
d. The LL(1)-checker would go into an infinite loop

Example
Consider the grammar

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

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). The predictive parsing table is a two-dimensional table called table.

Question 9
What does table(A,x) contain?

a. error
b. \(\epsilon\)
c. \{x C B\}
d. A x

Question 10
What does table(A,y) contain?

a. error
b. \(\epsilon\)
c. \{x C B\}
d. A x
Question 11
What does $table(A, z)$ contain?
- a error
- b $\epsilon$
- c $x C B$
- d $A x$

Question 12
What does $table(B, x)$ contain?
- a error
- b $\epsilon$
- c $z$
- d $A x$

Question 13
What does $table(B, y)$ contain?
- a error
- b $\epsilon$
- c $z$
- d $A x$

Question 14
What does $table(B, z)$ contain?
- a error
- b $\epsilon$
- c $z$
- d $A x$

Question 15
What does $table(C, x)$ contain?
- a error
- b $\epsilon$
- c $y B z$
- d $x C B$

Question 16
What does $table(C, y)$ contain?
- a error
- b $\epsilon$
- c $y B z$
- d $x C B$
Question 17
What does table$(C, z)$ contain?
- $a$ error
- $b$ $\epsilon$
- $c$ $y B z$
- $d$ $x C B$

Example
Consider the grammar
\[
\begin{align*}
A & ::= C z \mid x B \\
B & ::= z B x \\
C & ::= y A \mid \epsilon
\end{align*}
\]
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 next of type token, and that the program has three procedures $A()$, $B()$, $C()$, and the following main part:

```c
void main() {
    next = getnexttoken();
    A();
}
```

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

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

\begin{verbatim}
  if (next == x) {
    eat(x);
    B()
  }
  else {
    ????
  }
\end{verbatim}

What is “???”?
\begin{enumerate}
  \item \texttt{/* do nothing */}
  \item \texttt{error();}
  \item \texttt{C(); eat(z);}
  \item \texttt{if (next == y) { C(); eat(z); } else { error(); }}
\end{enumerate}

Question 19
The procedure \texttt{B()} looks like:

\begin{verbatim}
{
  ????
}
\end{verbatim}

What is “???”?
\begin{enumerate}
  \item \texttt{/* do nothing */}
  \item \texttt{error}
  \item \texttt{if ((next == x) or (next == z)) { eat(z); B(); eat(x); }}
  \item \texttt{if (next == z) { eat(z); B(); eat(x); } else { error(); }}
\end{enumerate}

Question 20
The procedure \texttt{C()} looks like:

\begin{verbatim}
if (next == y) {
  eat(y);
  A()
}
else {
  ????
}
\end{verbatim}

What is “???”?
\begin{enumerate}
  \item \texttt{/* do nothing */}
  \item \texttt{error();}
  \item \texttt{if (next == x) { /* do nothing */ } else { error(); }}
  \item \texttt{if (next == z) { /* do nothing */ } else { error(); }}
\end{enumerate}
Example
Consider the grammar:

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

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

Question 21
Which grammar generates the same language as the above grammar?

(a) \[
A ::= y \, A \, D \mid z \, D \\
B ::= x \, A \, y \, D \mid y \, D \\
D ::= x \, B \mid \epsilon
\]

(b) \[
A ::= y \, A \, D \mid z \, D \\
B ::= x \, A \, y \, D \mid y \, y \, D \\
D ::= x \, B \mid \epsilon
\]

(c) \[
A ::= y \, A \, D \mid z \, D \\
B ::= x \, A \, y \mid y \, D \\
D ::= x \, B \mid \epsilon
\]

(d) \[
A ::= y \, A \, D \mid z \, D \\
B ::= x \, A \, y \mid y \, y \, D \\
D ::= x \, B \mid \epsilon
\]

Example
Consider the grammar:

\[
A ::= x \, B \mid y \, x \, B \\
B ::= y \, x \mid y \, B \, x
\]

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?

a

\[ A ::= x x C \mid y x y C \]
\[ C ::= x \mid y C x \]

b

\[ A ::= x x C \mid y x y C \]
\[ C ::= x \mid y C y \]

c

\[ A ::= x y C \mid y x y C \]
\[ C ::= x \mid y C x \]

d

\[ A ::= x y C \mid y x y C \]
\[ C ::= x \mid y C y \]