1. (**Lexical Analysis, 22 pts**) In this section, alphabet $\Sigma = \{0, 1\}$.

   (a) (**6 pts**) Let $L_1 = \{$All string that contains **an even number of 1s** and **an odd number of 0s**$\}$. Construct an DFA or NFA that describes L_1. Your response should be sound and complete.

   (b) (**6 pts**) Draw an NFA that can represent the following regular expression:

   $$0(\mathbf{1}^* + 010)01 + 001$$

   Your response should be sound and complete.

   (c) (**10 pts**) Convert your NFA to the corresponding DFA. The answer is not unique, give out any.

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2. (**Syntax Analysis, 20 pts**) Consider the following **grammar** G_1'

$$A \to \mathbf{a}BA\mathbf{b}$$
$$A \to \mathbf{a}$$
$$B \to \mathbf{b}B$$
$$B \to \epsilon$$

whose start symbol is A.

(a) (**10 pts**) Draw the LR(1) Automaton of this grammar G.

(b) (**2 pts**) Identify a shift-reduce conflict of LR(1).

(c) (**8 pts**) If we solve shift-reduce conflict by always choosing to reduce, draw the parse tree of the following input

a b b a b

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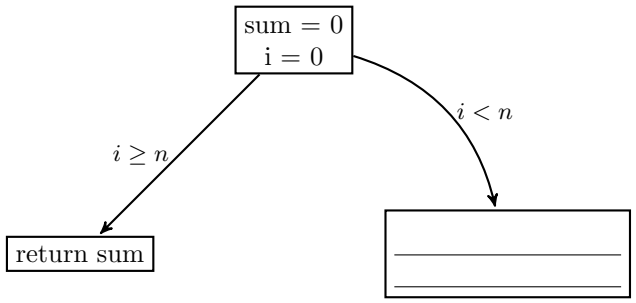
3. (**Intermediate Representation, 10 pts**) Read the given C function, complete the following tasks.

```
int f(int n) {
    int sum = 0;
    for (int i = 0; i < n; i++)
        sum += i;
    return sum;
}
```

(a) (**5 pts**) Complete the control flow graph.



(b) (**5 pts**) Complete the SSA-form.

Algorithm 1 Sum

1: $sum_1 = 0$
2: $i_1 = 0$
3: **L1:**
4: $i_2 = \varphi(\_\_\_\_\_, \_\_\_\_\_)$
5: **if** $i_2 \geq n$ **then**
6: **goto L2**
7: **end if**
8: $sum_2 = \varphi(sum_1, sum_3)$
9: $sum_3 = sum_2 + 1$
10: $i_3 = i_2 + 1$
11: _____
12: **L2:**
13: **return** $\varphi(sum_1, sum_3)$

4. (**Syntax Directed Translation, 24 pts**) Consider this Syntax-Directed Definition(SDD)

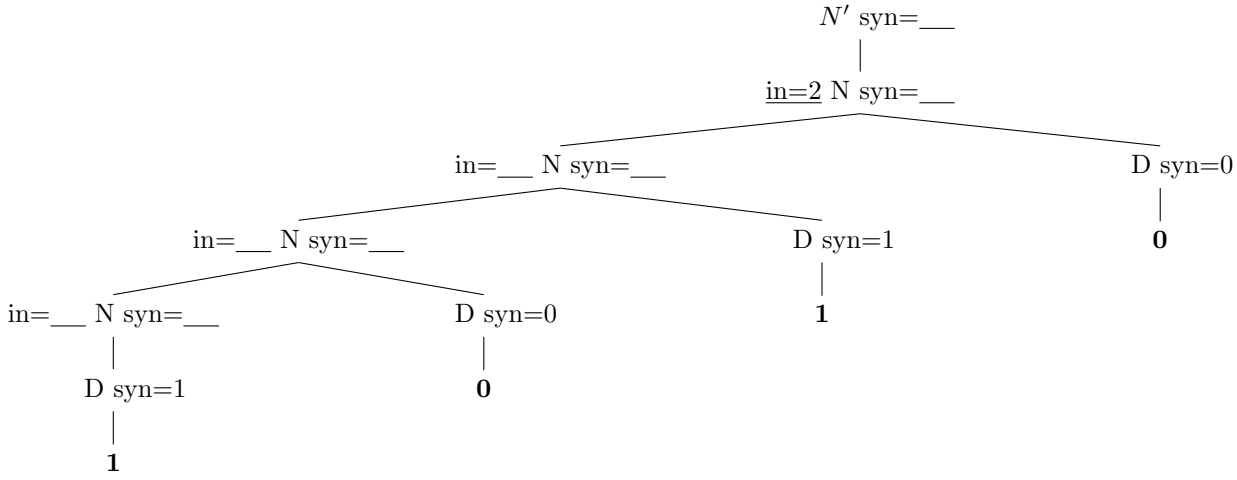
Production Rules	*Semantic Rules*
$N' \to N$	$N.\text{in} = 0, N'.\text{syn} = N_1.\text{syn}$
$N \to N_1\ D$	$N_1.\text{in} = N.\text{in} \times 2 + D.\text{syn}, N.\text{syn} = N_1.\text{syn}$
$N \to D$	$N.\text{syn} = N.\text{in} \times 2 + D.\text{syn}$
$D \to \mathbf{0}$	$D.\text{syn} = 0$
$D \to \mathbf{1}$	$D.\text{syn} = 1$

(a) (**4 pts**) Is this SDD L-attributed? Explain your answer short and clear.

(b) By this SDD, we parse the following input

1 0 1 0

into this annotated syntax parse tree



i. (**8 pts**) Fill out the missing values.

ii. (**8 pts**) Draw the dependency graph directly on this graph.

(c) (**4 pts**) Suppose the input is the input token sequence S, the output is N'.syn What is the relation between S and N'.syn?

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5. (**Type Checking, 24 pts**) This is the ChocoPy type checking rules(simplified),

$$\frac{O, M, C, R \vdash e_1 : int, e_2 : int}{O, M, C, R \vdash e_1 + e_2 : int}[\text{add}]$$

$$\frac{O, M, C, R \vdash id : T, e_1 : T_1, T_1 \leq_a T}{O, M, C, R \vdash id = e_1}[\text{assign}]$$

$$\frac{O, M, C, R \vdash e_1 : int, e_2 : int}{O, M, C, R \vdash e_1 \texttt{ == } e_2 : bool}[\text{int-equal}]$$

$$\frac{O, M, C, R \vdash e_0 : bool, e_1 : T_1, e_2 : T_2}{O, M, C, R \vdash e_1 \texttt{ if } e_0 \texttt{ else } e_2 : T_1 \bigsqcup T_2}[\text{if-else expr}]$$

Assume O environment has the following mappings:

$$O(a) = A, O(b) = B, O(c) = C, O(i) = int, O(n) = int$$

where A, B, C are classes that $A \leq_a C, B \leq_a C, A \not\leq_a B, B \not\leq_a A$. And $T_1 \bigsqcup T_2$ means the least common ancestor (LCA) of the type T_1 and T_2 in the tree-like type hierarchy defined by $\leq_a$.

(a) (**2 pts**) What are the meanings of "sound" and "complete" respectively?

(b) (**2 pts**) Does the statement '`a=c`' (where `=` is assignment) has any type error? Answer Yes or No.

(c) (**8 pts**) Show the type derivation of the statement '`c = b`'.

(d) (**12 pts**) Show the type derivation of the expression '`a if i + 1 == n else b`'.

End of This Exam Problem