

- 1) a) $\langle \text{program} \rangle ::= \langle \text{stmt} \rangle \{ \text{stmt} \}$
 $\langle \text{stmt} \rangle ::= \langle \text{assign} \rangle \mid \langle \text{if-stmt} \rangle \mid \langle \text{while-stmt} \rangle$
 $\langle \text{assign} \rangle ::= \langle \text{id} \rangle = \langle \text{expr} \rangle;$
 $\langle \text{if-stmt} \rangle ::= \text{if} (\langle \text{expr} \rangle) \langle \text{stmt} \rangle [\text{else} \langle \text{stmt} \rangle]$
 $\langle \text{while-stmt} \rangle ::= \text{while} (\langle \text{expr} \rangle) \langle \text{stmt} \rangle$
 $\langle \text{expr} \rangle ::= \langle \text{term} \rangle \{ (+|-) \langle \text{term} \rangle \}$
 $\langle \text{term} \rangle ::= \langle \text{factor} \rangle \{ (*|/) \langle \text{factor} \rangle \}$
 $\langle \text{factor} \rangle ::= \langle \text{id} \rangle \mid \langle \text{number} \rangle \mid (\langle \text{expr} \rangle)$
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- b) $\langle \text{function-call} \rangle ::= \langle \text{id} \rangle (\langle \text{opt-arg-list} \rangle)$
 $\langle \text{opt-arg-list} \rangle ::= \langle \text{arg-list} \rangle \mid \epsilon$
 $\langle \text{arg-list} \rangle ::= \langle \text{expr} \rangle \langle \text{arg-list-tail} \rangle$
 $\langle \text{arg-list-tail} \rangle ::= \langle \text{expr} \rangle \langle \text{arg-list-tail} \rangle \mid \epsilon$
 $\langle \text{declaration} \rangle ::= \langle \text{type} \rangle \langle \text{id} \rangle \mid \langle \text{type} \rangle \langle \text{id} \rangle = \langle \text{expr} \rangle$
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- c) $\langle \text{or-expr} \rangle ::= \langle \text{or-expr} \rangle \text{ or } \langle \text{and-expr} \rangle$
 $\langle \text{and-expr} \rangle ::= \langle \text{and-expr} \rangle \text{ and } \langle \text{not-expr} \rangle \mid \langle \text{not-expr} \rangle$
 $\langle \text{not-expr} \rangle ::= \text{not } \langle \text{not-expr} \rangle \mid \langle \text{primary} \rangle$
 $\langle \text{primary} \rangle ::= \text{true} \mid \text{false} \mid (\langle \text{or-expr} \rangle)$

2a) $\langle S \rangle$

$\langle S \rangle \Rightarrow \langle A \rangle \langle B \rangle \langle C \rangle$

$\Rightarrow a \langle A \rangle \langle B \rangle \langle C \rangle$

$\Rightarrow a a \langle B \rangle \langle C \rangle$

$\Rightarrow a a b \langle B \rangle \langle C \rangle$

$\Rightarrow a a b b \langle B \rangle \langle C \rangle$

$\Rightarrow a a b b b \langle C \rangle$

$\Rightarrow a a b b b c \langle C \rangle$

$\Rightarrow a a b b b c c$

Final string: $a b b b c c$

b) $a + b * 3 + c$

$\langle \text{expr} \rangle$

$\langle \text{expr} \rangle + \langle \text{term} \rangle$

$\langle \text{expr} \rangle + \langle \text{term} \rangle \langle \text{factor} \rangle$

$\langle \text{term} \rangle \langle \text{term} \rangle *$

$\langle \text{term} \rangle$

$\langle \text{id} \rangle$

$\langle \text{factor} \rangle$

$\langle \text{factor} \rangle$

$\langle \text{number} \rangle$

$\langle \text{id} \rangle$

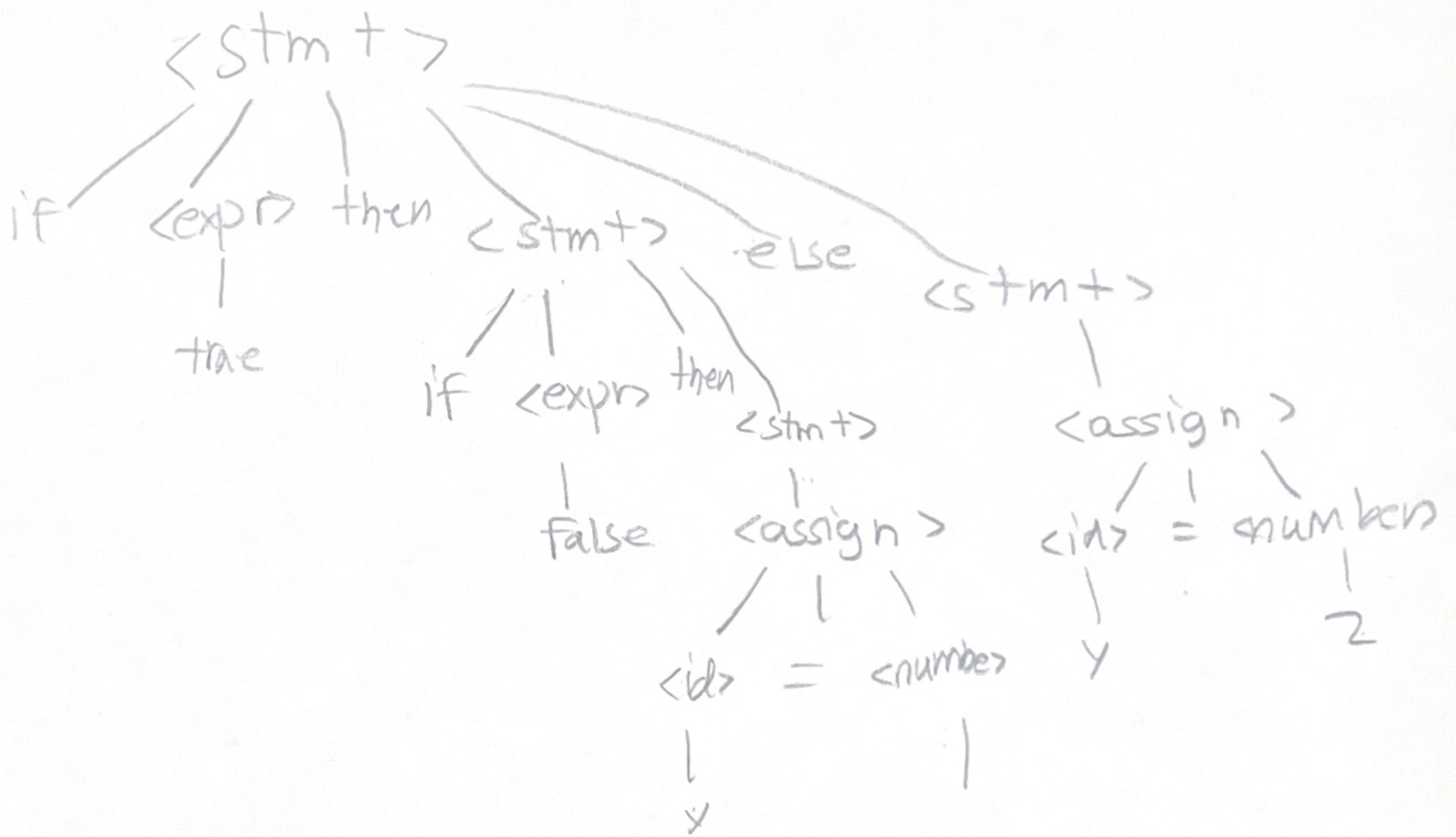
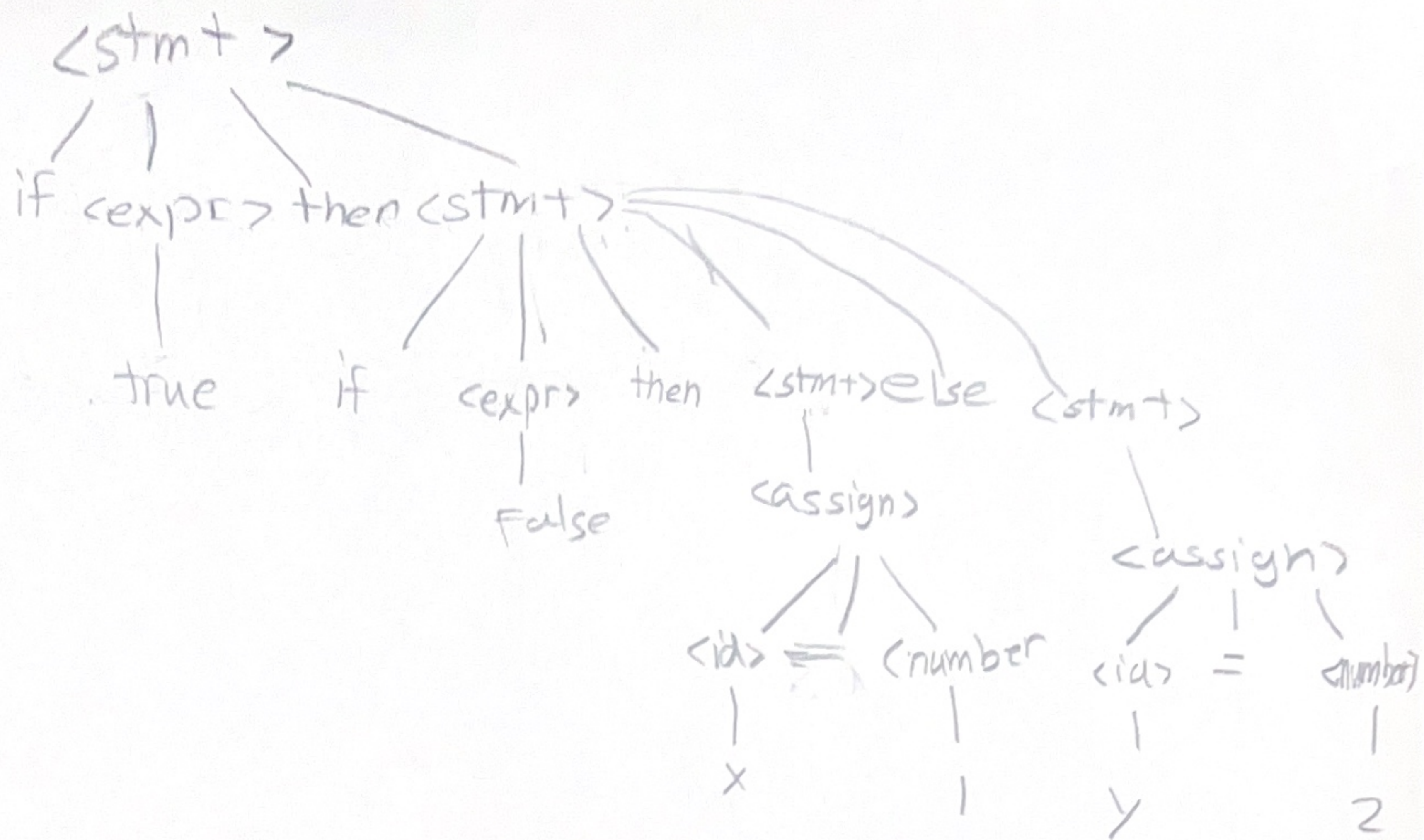
$\langle \text{id} \rangle$

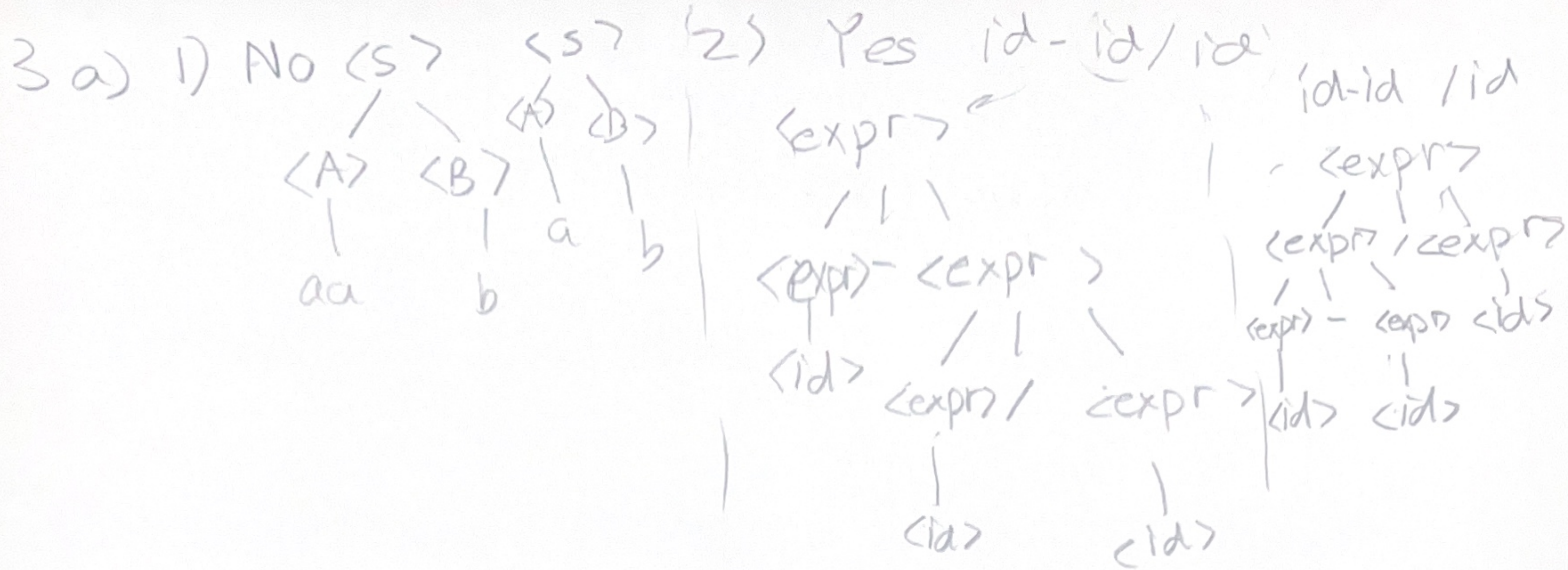
3

9

6

2c)





b) $\langle expr \rangle ::= \langle add \rangle$

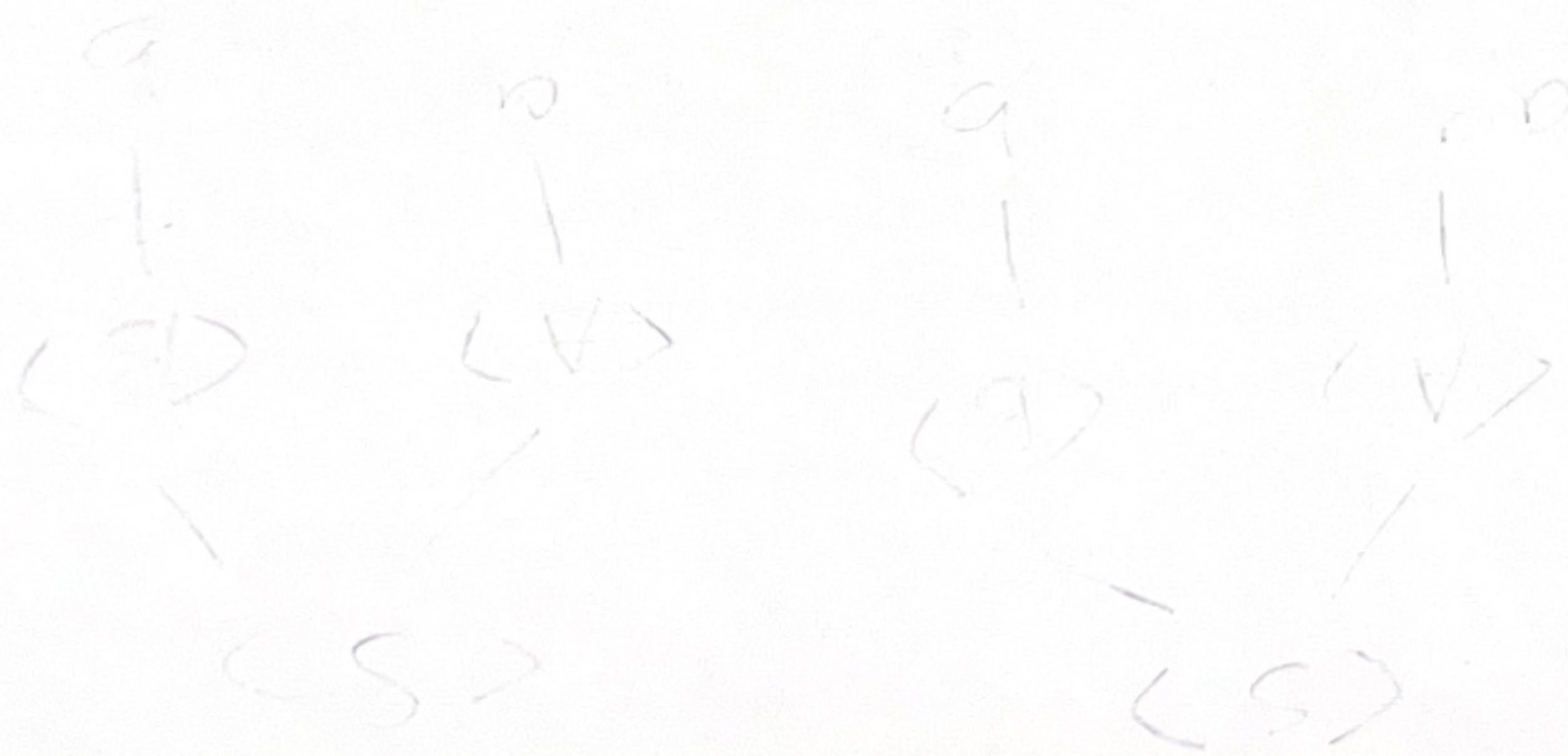
$\langle add \rangle ::= \langle add \rangle + \langle mul \rangle \mid \langle add \rangle - \langle mul \rangle \mid \langle mul \rangle$

$\langle mul \rangle ::= \langle mul \rangle * \langle pow \rangle \mid \langle mul \rangle / \langle pow \rangle \mid \langle pow \rangle$

$\langle pow \rangle ::= \langle Atom \rangle ^ \langle pow \rangle \mid \langle Atom \rangle$

$\langle Atom \rangle ::= (\langle expr \rangle) \mid \langle number \rangle$

2) Yes $id - id / id$



3 a) 1) No