1. Fill in the blanks below with the correct expressions. [1×5=5]

(a) Given a grammar $G = (V, T, P, S)$, a symbol $X \in V \cup T$ is said to be

(i) **useful** if ________________;

(ii) **nullable** if ________________.

(b) Given a grammar $G = (V, T, P, S)$, a production $A \rightarrow X_1 \ldots X_n$ is said to be a unit production if ________________.

(c) Given a pushdown automaton (PDA) $P = (Q, \Sigma, \Gamma, \delta, q_0, Z_0, F)$, the language accepted by $P$

(i) by **final state** is given by $L(P) = \{ w \mid \vdash_P^* \}$;

(ii) by **empty stack** is given by $N(P) = \{ w \mid \vdash_P^* \}$.

2. Recall that **postfix notation** is a method for writing arithmetic expressions in which every operator is written after all of its operands. For example, the postfix equivalent of $A \times B + C/D$ is $AB \times CD/+$. Write a context-free grammar (CFG) for arithmetic expressions in postfix notation involving variables and the operators $+, -, \times$ and $/$. You may assume that variable names consist of single letters only (as in the example above). You should use a single non-terminal $S$. [3]

**Answer:**

P.T.O.
3. Let $L = \{ w \mid w \text{ is obtained by taking a syntactically correct C program and removing everything}\
on\text{other than the keywords if and else from it}\}$. Draw the state diagram of a PDA that accepts $L$ by empty stack. You may assume that if and else are single symbols. [7]

4. Let $G = (V, T, P, S)$ be a CFG in Greibach Normal Form. Let $|V| = n$, $|T| = m$, $|P| = p$. Suppose that $p_0$ of the productions are of the form $A_0 \rightarrow aA_1A_2 \ldots A_k$ where $k$ is a fixed number, $A_i \in V$ for $0 \leq i \leq k$ and $a \in T$. The remaining productions are of the form $A \rightarrow a$ where $a \in T$. Let $G' = (V', T, P', S)$ be a CFG in Chomsky Normal Form (CNF) obtained from $G$ using the standard algorithm for conversion to CNF. Then:

$|V'| \leq \ldots \ldots \quad |P'| \leq \ldots \ldots$

Your bounds should be tight. Briefly justify your answer. [5]