1.) S → NP | VP
N → Boy | school
NP → the N | NP that VP
VI → went AD | reached AD
AD → to | by
VT → drives | walks.
VP → VT | VI NP.

a) optimized grammar:

S → NP VP
N → boy | school
NP → then N | NP that VP
VP → VT | VI NP
VT → drives | walks
VI → went
AD → to | by.

b) chomsky Normal form:-

S → NP VP
N → boy | school
NP → then N | NP that VP
VP → VT | VI NP
VT → drives | walks
VI → went
NP → ADN
AD → to | by

c) Greibach Normal form:- (GNF):-

S → NPVP
N → b | S
Nb → t N | NP tt VP
VP → vt | vw NP
VT → d | w
VI → we
NP → at N
AD → t | b

d) Derivation & parse tree for "the boy went to school".

→ Leftmost Derivation:

S ⇒ NP VP
⇒ the N VP
⇒ the boy VP
⇒ the boy VI NP
⇒ the boy went NP
⇒ the boy went ADN
⇒ the boy went to N
⇒ the boy went to school

→ Rightmost Derivation:

S ⇒ NP VP
⇒ the N VP
⇒ the boy VP
⇒ the boy VI NP
⇒ the boy went NP
⇒ the boy went to N.
⇒ the boy went to school.

→ Parse tree :-
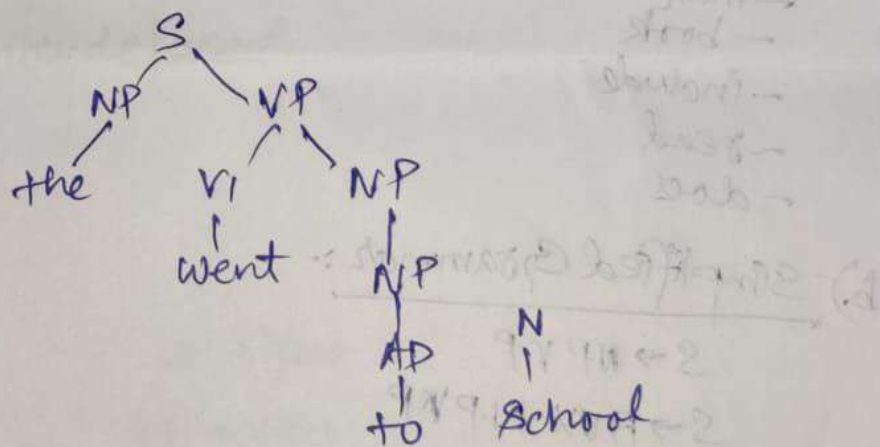
2) S → NP VP

S → AUX NP VP

S → UP

NP → Det NOM

NOM → Noun

NOM → NOUM NOM

VP → verb

VP → verb NP

Det → that | this | a | the

Noun → book | flight | meal | man

verb → book | include | read

AUX → does

a) **Terminal symbols:**

- that
- this
- a
- the
- book
- flight
- meal
- man
- book
- include
- read
- does

Non-terminal symbols :-

- S
- NP
- VP
- AUX
- NOM
- Det
- Noun
- Verb

b.) **Simplified Grammar :-**

$S → NP\ VP$

$S → AUX\ NP\ VP$

$S → VP$

$NP → Det\ NOM$

$NOM → Noun.$

$NOM → Noun\ NOM$

$VP → Verb$

$VP → verb\ NP$

Det → that | this | a | the

Noun → book | flight | meal | man

Verb → book | include | read

AUX → does

c) **Chomsky Normal form :-**

S → NP VP.

S → AUX NP VP.

S → VP

NP → Det NOM

NOM → Noun.

NOM → Noun NOM.

VP → Verb.

VP → Verb NP.

Det → that | this | a | the

Noun → book | flight | meal | man

Verb → book | include | read

AUX → does

d) **CFG to GNF :-**

S → NP VP

S → AUX NP VP

S → VP

NP → Det NOM.

NOM → Noun NOM.

NOM → Noun NOM.

NOM → ε

VP → does NP

VP → Verb

Det → that | this | a | the.

Noun → book | flight | meal | man.

Verb → book | include | read.

AUX → does

e) **string** :- " The man does include this book" is accepted.

$$S \to NP\,VP$$
$$NP \to Det\,NOM$$
$$Det \to the$$
$$NOM \to Noun$$
$$Noun \to man$$
$$VP \to verb\,NP$$
$$Verb \to include$$
$$NP \to Det\,NOM$$
$$Det \to this$$
$$NOM \to Noun$$
$$Noun \to Book$$

---

q3.) $L = a^r b$

δ
C
K

① $J = \int + K / J , K \geqslant 0$

a) $A \to J = \int + K$

$L \to \varepsilon$
$B \to b$

b) $A \to J = \int + K$

$L \to \varepsilon$
$B \to b$
$A \to L$

c.) **CNF** :-

$L \to \varepsilon$
$A \to J = \int + K$
$L \to \varepsilon | B$
$B \to b$
$A \to L | J \to MOM$
$A \to J = JK | L$
$J \to \delta$
$K \to K$
$B \to b$
$A \to XZ | L$
$X \to J$
$Z \to JK$

$| J \to \int$
$| K \to k$
$| B \to b$

② **GNF** :-

$A \to JY | Z$
$Y \to = \int K$
$Z \to L$
$L \to \varepsilon | B$
$J \to \delta$
$K \to K$
$B \to b$

e.) **Parse Tree** :-

A
$\downarrow$
$J Y$
$\downarrow$
$J = JK$
$\downarrow$
$J = \int + k$
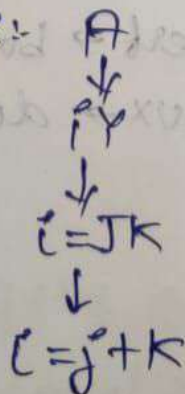
BLOCK → STMT{; STMTS}

STMTS → ε | STMT STMTS

STMT → EXPR ; | if (EXPR) BLOCK | while (EXPR)

BLOCK | do BLOCK while (EXPR); | BLOCK

EXPR → identifier | constant | EXPR + EXPR | EXPR - EXPR |

EXPR * EXPR | EXPR / EXPR

1.) Remove useless production :-

BLOCK → STMT

STMTS → ε | STMT STMTS

STMT → EXPR ;

EXPR → identifier | constant | EXPR + EXPR | EXPR - EXPR |

EXPR * EXPR | EXPR | EXPR

2.) Remove the Null production :-

BLOCK → STMT
STMTS → ε | STMT STMTS

STMT → EXPR ;

EXPR → identifier | constant | EXPR + EXPR | EXPR - EXPR |

EXPR * EXPR | EXPR / EXPR | ε

3.) Remove the unit productions

the grammar has no unit productions.

4) Convert to GNF:

BLOCK → STMT | { }

STMTS → ε | STMT STMTS

STMT → EXPR;

EXPR → identifier | constant | EXPR+EXPR |
EXPR-EXPR | EXPR*EXPR | EXPR / EXPR

5) provide examples for string acceptance & rejection:

Example 1:

"if $(x+y)$ { $z = x * 2;$ }" Accepted.

"while $(2 < 10)$ { $x = x + 1;$ }" Rejected

Example 2:

"{ }" → Accepted

"$x = 5;$" → Rejected.