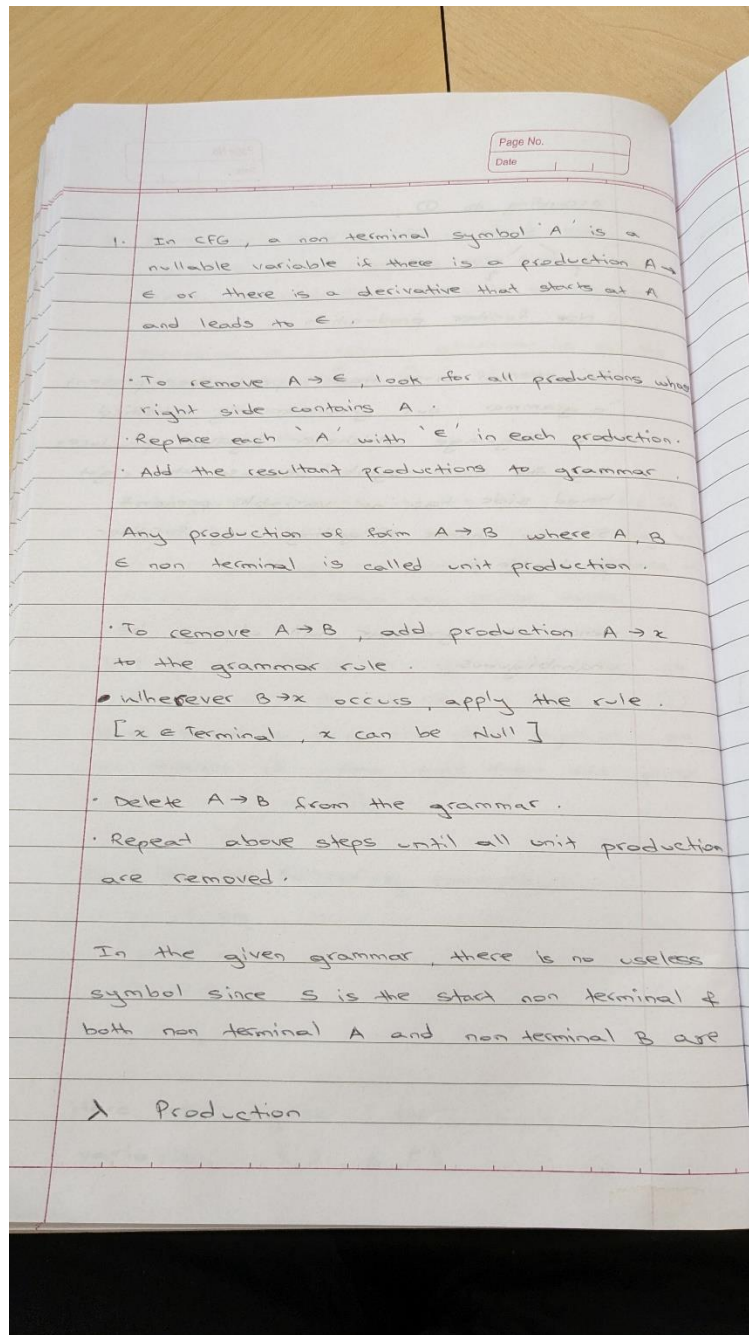


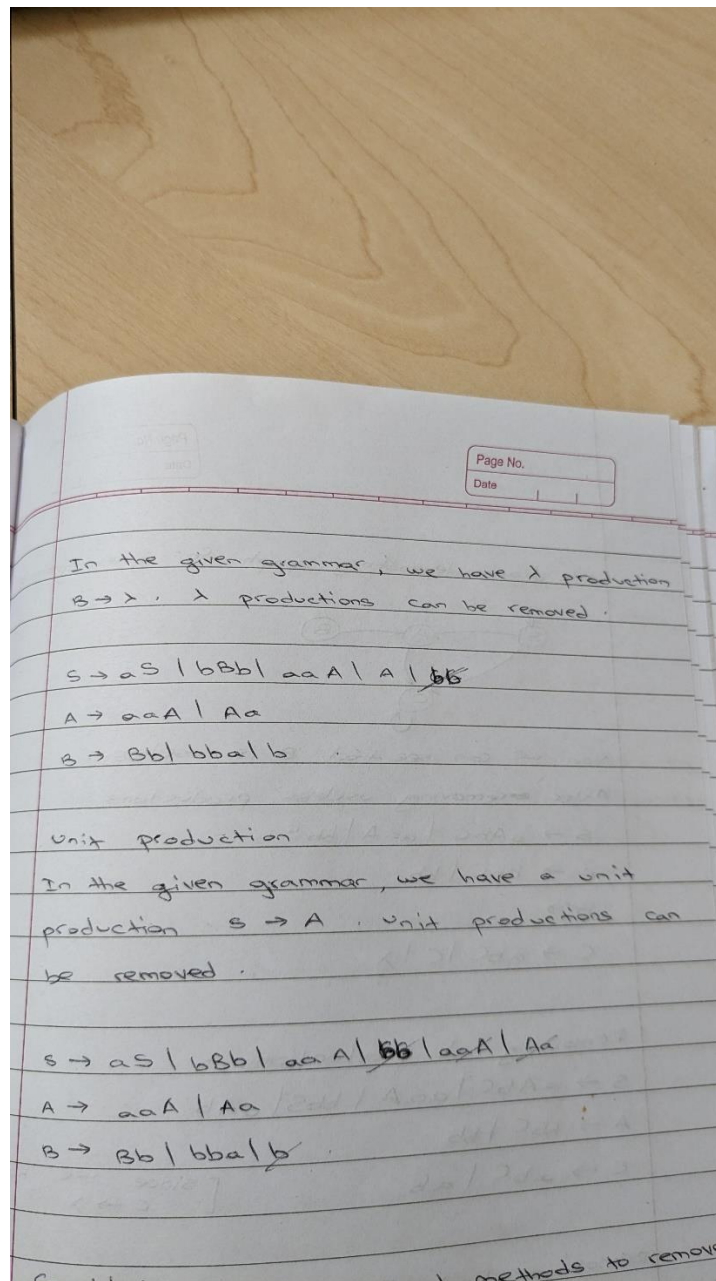
1. Remove all useless productions, λ -productions, and unit productions from the following grammar (without introducing any new useless productions, λ -productions, or unit productions):

$S \rightarrow aS \mid bBb \mid aaA \mid A$

$A \rightarrow aaA \mid Aa$

$B \rightarrow Bb \mid bba \mid \lambda$





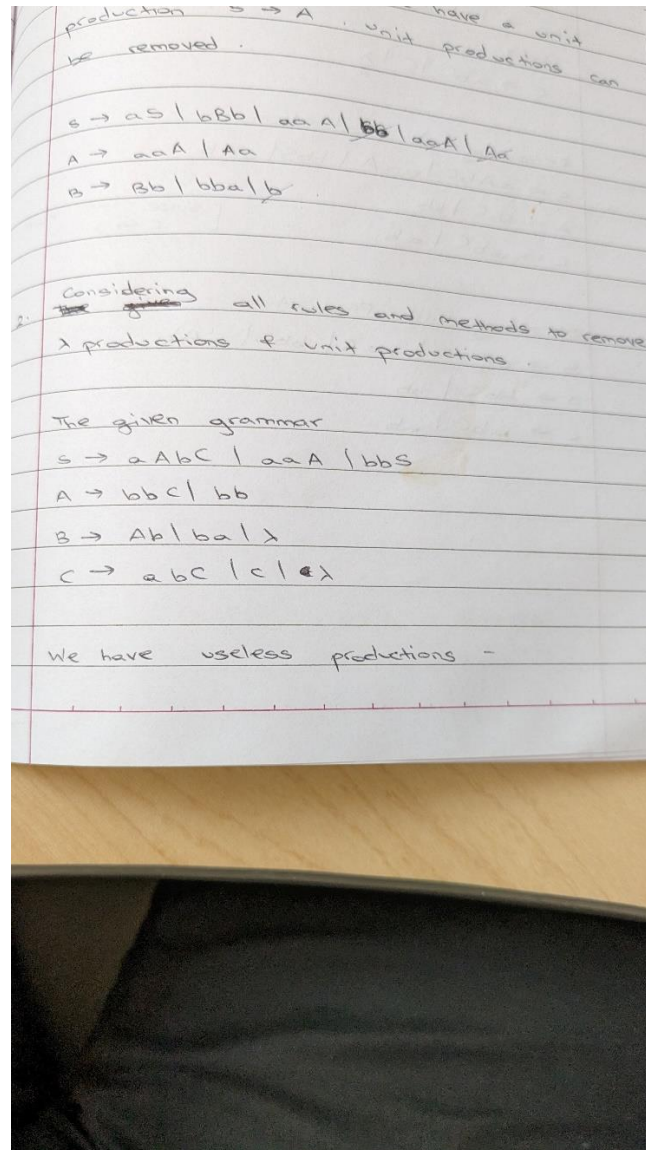
2. Remove all useless productions, λ -productions, and unit productions from the following grammar (without introducing any new useless productions, λ -productions, or unit productions):

$S \rightarrow aAbC \mid aaA \mid bbS$

$A \rightarrow bbC \mid bb$

$B \rightarrow Ab \mid ba \mid \lambda$

$C \rightarrow abC \mid C \mid \lambda$



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We draw dependency graph for given grammar

```

graph LR
    S((S)) --> S
    S --> A((A))
    S --> C((C))
    A --> B((B))
    B --> A
    C --> A
    C --> C
  
```

Now, we can see that B is useless.

After removing useless productions :-

$$S \rightarrow \epsilon ABC / aaA / bbS$$

$$A \rightarrow bbC / bb$$

$$B \rightarrow$$

$$C \rightarrow abc / C / \lambda$$

Removing λ productions :-

$$S \rightarrow aABC / aaA / bbS / aAb$$

$$A \rightarrow bbC / bb$$

$$C \rightarrow abc / ab \quad [\text{since we have } C \rightarrow \lambda]$$

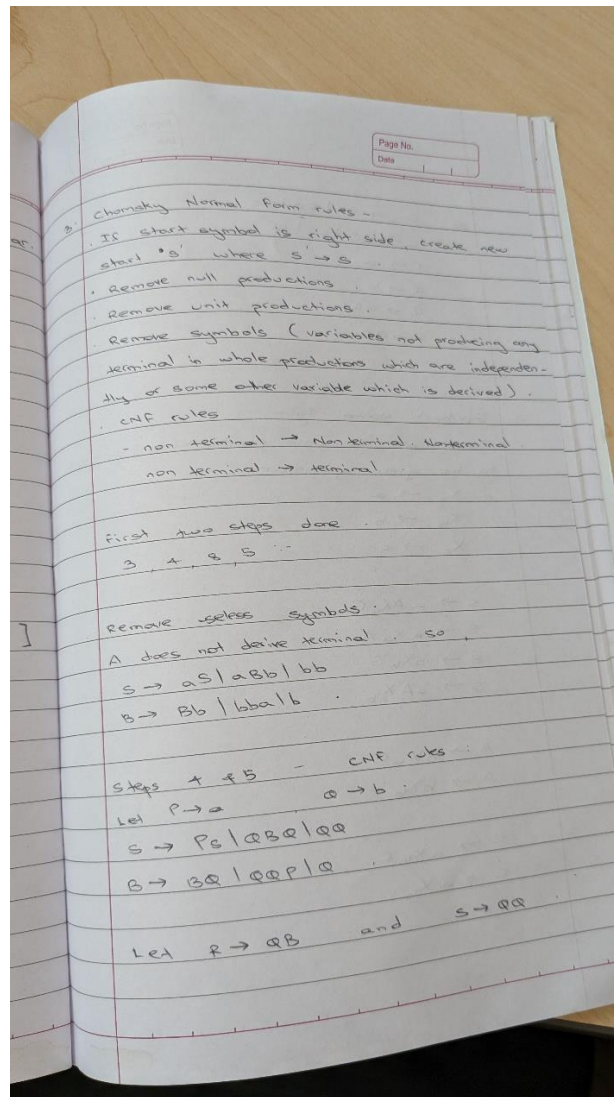
Removing Unit Productions :-

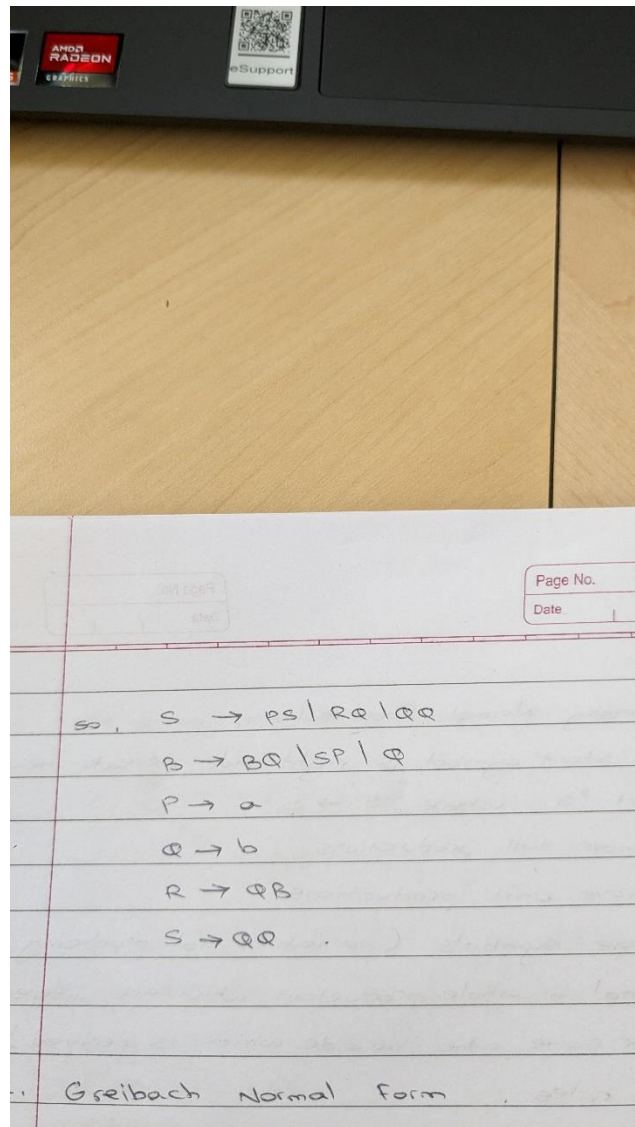
$$S \rightarrow aABC / aaA / bbS / aAb$$

$$A \rightarrow bbC / bb$$

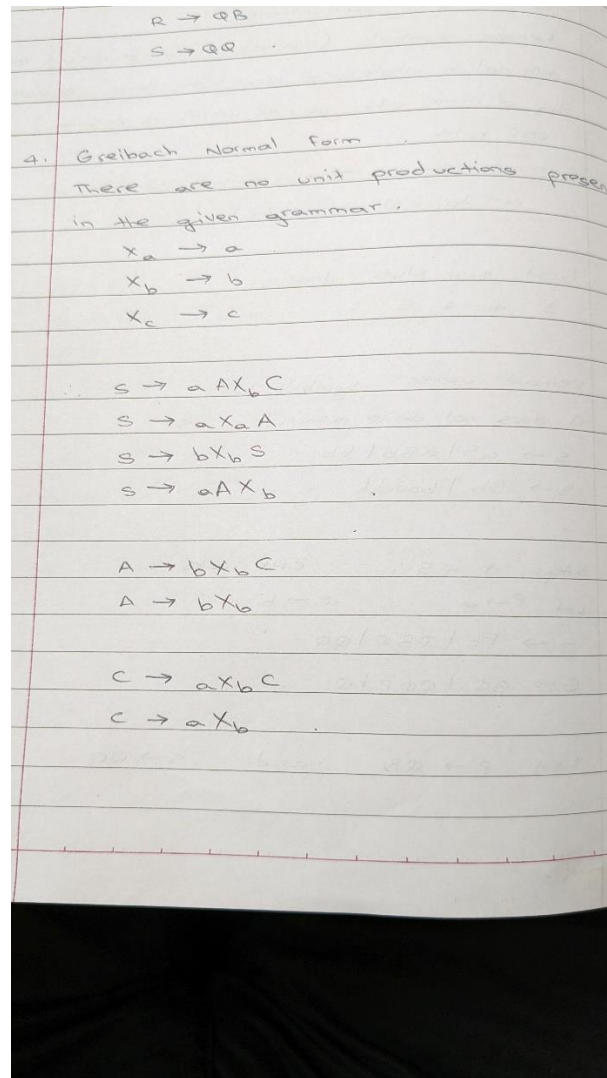
$$C \rightarrow abc / ab$$

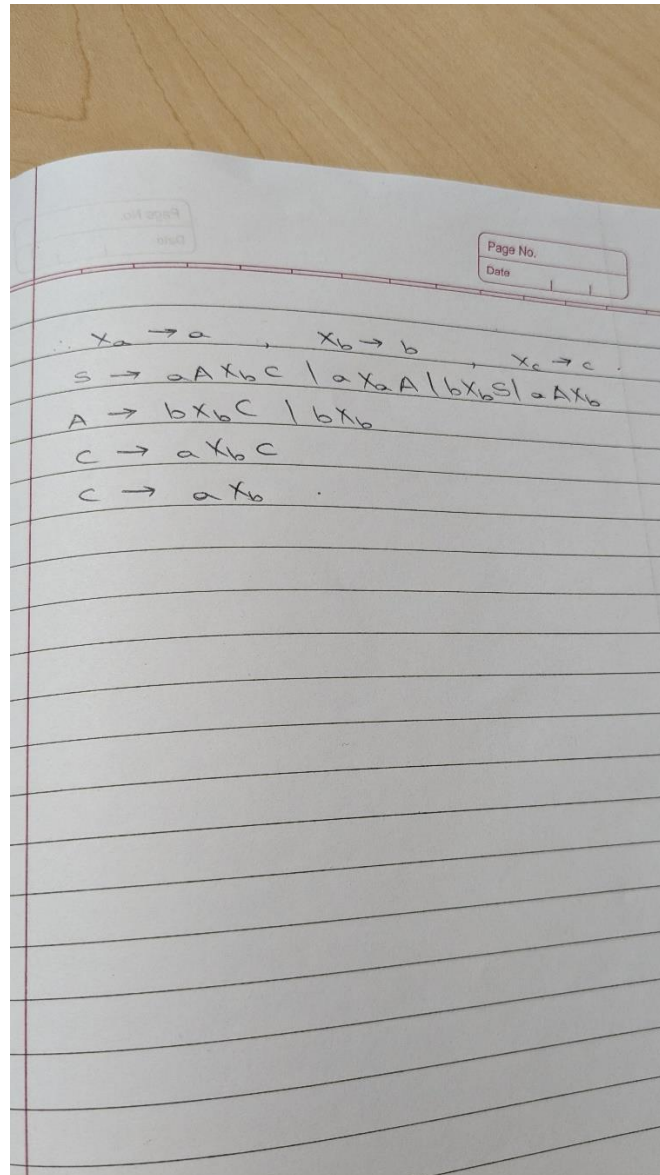
3. Convert the grammar from #1 to Chomsky normal form.



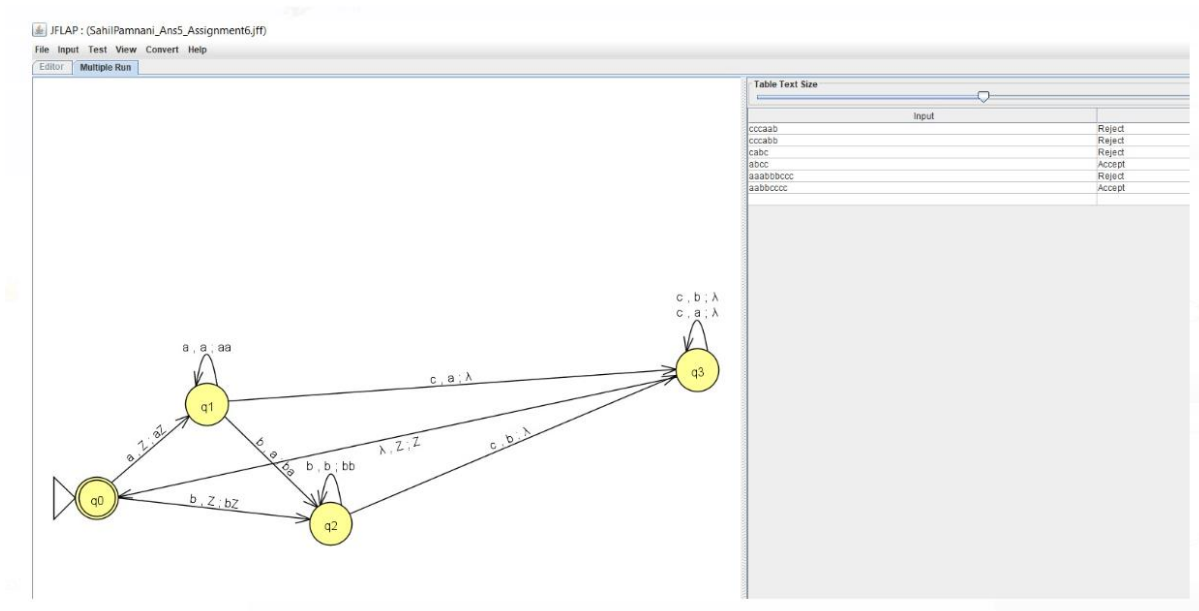


4. Convert the grammar from #2 to Greibach normal form.





5. Create a npda for the language $L = \{a^x b^y c^z : z = x + y\}$.



6. Create a npda for the language $L = \{a^n b^n : n \text{ is not a multiple of } 3\}$ (zero should be considered a multiple of 3).

