Check whether the following languages are DCFL, CFL or not ?

$L_1 = \{a^n b^n \mid n \geq 0\}$ ⇒ DCFL

$L_2 = \{a^n b^{2n} \mid n \geq 0\}$

$L_3 = \{a^{2n} b^n \mid n \geq 0\}$

$L_4 = \{a^m b^m c^n d^n \mid m, n \geq 0\}$

$L_5 = \{a^m b^n c^n d^m \mid m, n \geq 0\}$

DCFL

$L_6 = \{a^m b^n c^m d^n \mid m, n \geq 1\}$ → CSL

↳ ✗ CFL

$L_7 = \{a^m b^{m+n} d^n \mid m, n \geq 1\}$

$= \{a^m b^m b^n d^n\}$

DCFL

$L_8 = \{a^{m+n} b^m c^n \mid m, n \geq 1\}$

DCFL $= \{a^m a^n b^m c^n \mid$

$L = \{a^m b^m c^n d^n a^k b^k \mid m, n, k \geq 1\}$ DCFL

$L = \{a^m b^m c^n d^n \mid m \geq n \geq 0\}$ ⇒ not CFL

$a^5 b^5 c^4 d^4$

$L = \{a^{2n} b^{3n} \mid n \geq 0\}$ ⇒ DCFL

aa → aaaa

$L = \{ a^{kn} b^{pn} \mid k, p \text{ are Constant}, n \geq 0 \}$ ⇒ DCFL

$a^{5n} b^{7n}$

for Every k a's push p a's in the stack

~~Pop b~~

$b \rightarrow a$ pop

DCFL
=

$L = \{a^m b^n \mid m > n \geq 0\}$

$m < n$

$\Rightarrow m \neq n$

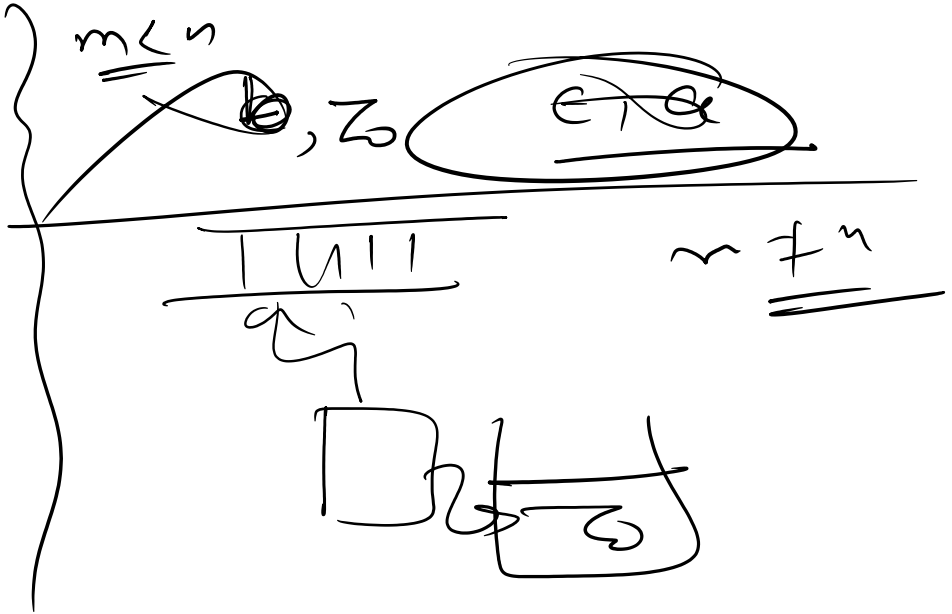
$m = n$

$m \leq n$

$m \geq n$

$m = 2n+1$

$m =$



$L = \{a^m b^n c^{(m \neq n)} \mid m, n \geq 1\}$ → CSL

$L = \{a^{n^2} \mid n \geq 1\}$ ⟹ CSL

$L = \{a^m b^n c^{m \div n} \mid m, n \geq 1$

$= \{a^{nx} b^n c^x$ → $m = x$

$\frac{m}{n}$

Concept $m = nx$

CSL ⟹

$n!$ $\quad n = O(n^n)$

$L = \{a^{n!}$ $\quad n!$

$n \neq n - n$ (2)

$L = \{ a^{m-n} b^m c^n \mid m, n \geq 1 \}$

⇒ a b ↪ DCFL

a) DCFL
b) CFL
c) Regular
d) None

$a^{6-2} b^6 c^2$

$a^4 b^6 c^2$

$\Rightarrow a^m b^{m+n} c^n$

$a^m b^m b^n c^n$

$L = \{a^n b^n \mid n \geq 0\} \cup \{a^{2n} b^{2m} \mid m \geq 0\}$

L_1 $\quad \cup \quad$ L_2 → Even Node & Even Edges

$L \Rightarrow \{a^n b^n \mid n \geq 0\}$ → DCFL

a) DCFL
b) NDCFL
c) Regular
d) None

$L = \{a^n b^n \cup a^m b^{2m} \mid m \geq 0\}$
$n \geq 0$

→ NDCFL

$L = \{a^i b^j c^k \mid i = j \text{ or } j = k,\ i, j, k \geq 0\}$

$\Rightarrow$ NDCFL

$|x| = 10$

$L = \{wcw^R \mid w \in (a,b)^*\}$ DCFL

✓ $L = \{wxw^R \mid w, x \in (a,b)^+\}$

$\{x \mid x \in (a,b)^*\}$

a) DCFL but not Regular

b) Regular

c) CFL but not DCFL

d) None

$\wedge$ a b b a b b b a $\wedge$

w ... x ... w^r

$L = \{ w x w^R \mid w, x \in (a,b)^*, |x| = 2 \}$

$w \{aa + as + La + bb\} w^R$

HDCFL

$L = \{ w (a+b) w^R \mid w \in (a,b)^* \}$

abbabbb

$L = \{ wcw \mid a \in (a,b)^* \}$ X

abbcabb

Queue = 28 mer → DFA

$L = \{ w x w \mid w, x \in (a,b)^* \} \Rightarrow \{ x x^R \mid x \in (a,b)^* \} \rightarrow RL \Rightarrow DCFL$

$= \{ a b b a \; a b b a \}$

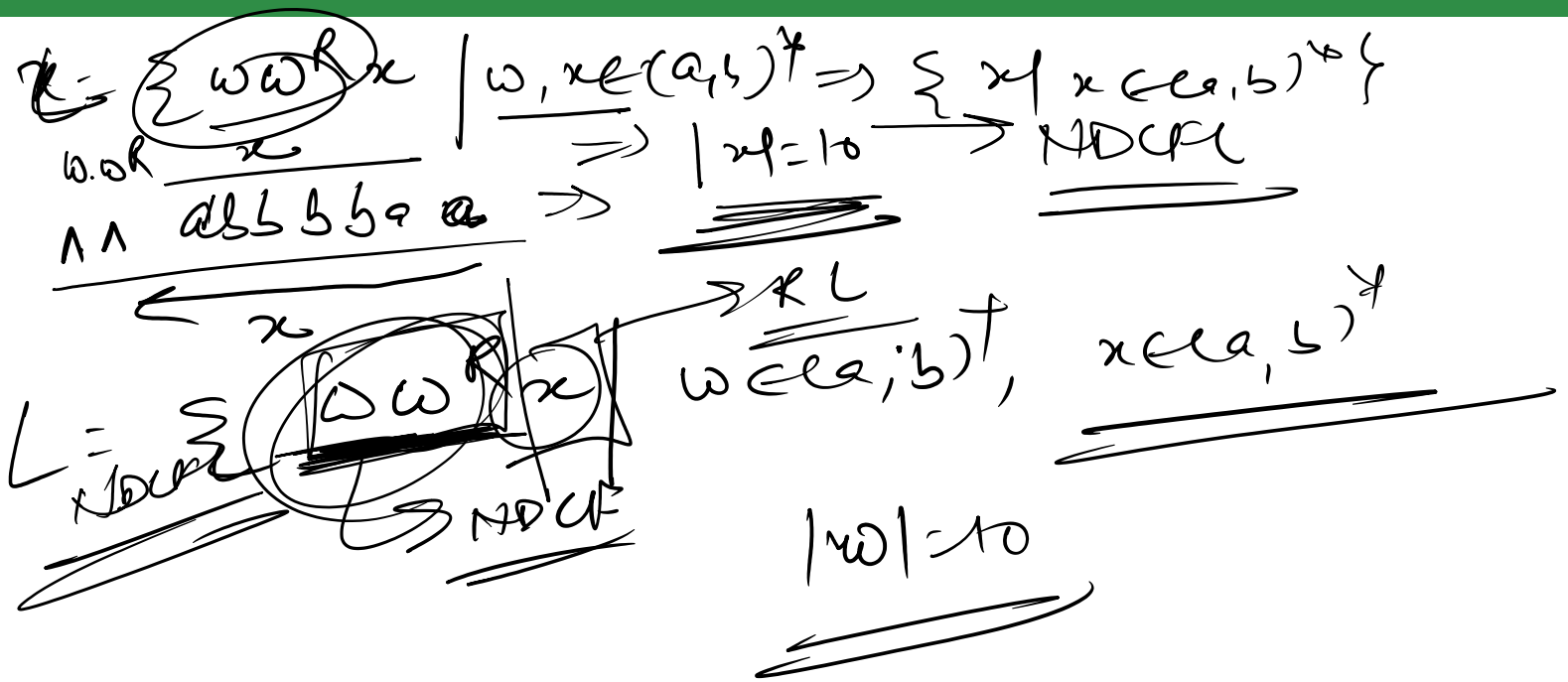
$RL \Rightarrow Reg \Rightarrow CSL \in CFL$

$L = \{ w x w^R \mid w \in (a,b)^+, x \in (a,b)^* \} \Rightarrow D$

$abb\,ab\,bba \Rightarrow L = a(a+b)^*a + b(a+b)^*b$

$w \; x \; w^R$

$\rightarrow RL$



$L = \{ w \# w \mid w \in (a,b)^+, x \in (a,b)^+ \}$

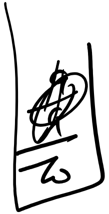
$|w| = 10$

(a) → CSL

(Theory of Computation)

$L_1 = \{ a^n b^n (a+b)^* \mid n > 0 \}$

$L_2 = \{ (a+b)^* b^n a^n \mid n > 0 \}$



Reg

DCFL

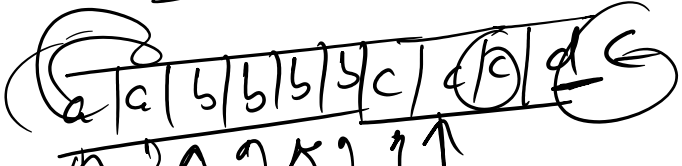
NDCFL

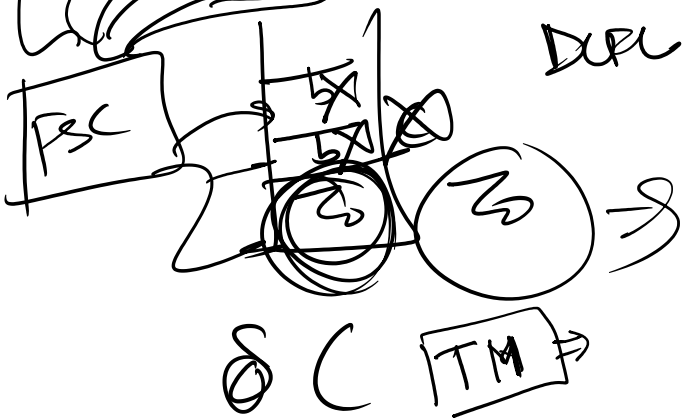
abbbbbaa

$L = \{a^m b^n | c^k d^l | m, n, k, l \geq 1\}$ $m+k = n+l$

2018 DCFL

$L = \{a^m b^n | c^k d^l$ 3:30



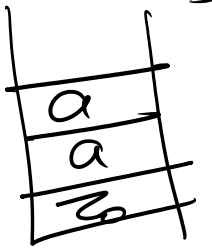


DCFL $L = \{a^m b^n c^k d^l | m, n, k, l \geq 1\}$

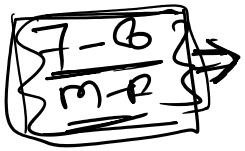
$a^4 b^2 c^1 d^3$ DCFL DPP 10

$a^2 b^4 c^3 d^1$

aa bbbb ccc d



b 6-7



Properties of CFL & DCFL

DCFL are not closed Under:

- Union
- Intersection
- Set Difference
- Homomorphism
- Kleen's closure
- Reversal
- Concatenation

$L_1 = \{a^n b^n \mid n \geq 0\}$ NDCFL

$L_2 = \{a^n b^{2n} \mid n \geq 0\}$

$L_1 = \{a^n b^m c^m \mid m, n \geq 0\}$

$L_2 = \{a^m b^m c^n \mid m, n \geq 0\}$

$L_1 \cap L_2 = \{a^m b^m c^m \mid m \geq 0\}$

↳ CSL

DCFL are closed Under:-

- Compliment ✓
- Inverse Homomorphism ✓
- Prefix ✓
- Suffix ✓
- Quotient ✓
- Union with regular ✓
- Intersection with regular ✓
- Set difference with regular ✓

Context free Language (CFL) are closed Under:

- Union ✓ CFL
- Concatenation
- Homomorphism ✓
- Invesse Homomorphism
- Kleen closure
- Positive closure ✓
- Quotient $S \rightarrow S_1, S_2$
- Prefix
- Suffix
- Reversal
- Cycle

- Union with regular ✓ CFL
- Intersection with regular → CFL
- Set difference with regular → CFL

CFL are not closed Under:-

- Intersection ✗
- Complement ✗
- Set difference
- Subset
- Superset
- Infinite Union
- Infinite Intersection
- Infinite set difference
- max
- min
- ALT
- HALF

Ex:- Let L_1 is CFL, L_2 is DCFL and L_3 is Regular

(i) $L_1 - L_3$? ⇒ CFL ∩ Regular ⇒ CFL ∩ Reg ⇒ CFL

(ii) $L_3 - L_1$? $L_3 - L_1 \Rightarrow L_3 \cap L_1' \Rightarrow$ Reg ∩ CSL ⇒ CSL

⇒ Reg ∩ CSL

(iii) $L_2 - L_3$? ↳ DCFL ∩ Regular

↳ DCFL ∩ Regular ⇒ DCFL

(iv) $L_3 - L_2$? Regular ∩ DCFL

Regular ∩ DCFL ⇒ DCFL

(v) CFL ∩ Regular ? CFL

(vi) CFL ∪ Regular ? CFL

Operations	RL	CFL	DCFL	CSL	Rec	REL
Union	✓	✓	×	✓	✓	✓
Intersection	✓	×	×	✓	✓	✓
Set Difference	✓	×	×	✓	✓	×
Complementation	✓	×	✓	✓	✓	×
Intersection with Regular	✓	✓	✓	✓	✓	✓
Concatenation	✓	✓	×	✓	✓	✓
Kleen Closure	✓	✓	×	✓	✓	✓
Kleen Plus	✓	✓	×	✓	✓	✓
Reversal	✓	✓	×	✓	✓	✓
Homomorphism	✓	✓	×	×	×	✓
ε-free Homomorphism	✓	✓	×	✓	✓	✓
Inverse Homomorphism	✓	✓	✓	✓	✓	✓
Substitution	✓	✓	×	×	×	✓
ε-free Substitution	✓	✓	×	✓	✓	✓
Quotient with Regular	✓	✓	✓	×	×	✓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