[9-1] $0^a 1 0^b 1 0^{a+b} \Rightarrow \sqcup 0^{a-1} 1 0^b 1 0^{a+b}$

$0 \sim \sqcup$ $0 \sim 0$

$\downarrow$

$0^a 0^b 1 0^{a+b} = 0^{a+b} 1 0^{a+b}$

$\downarrow$

$w \# w$ $\quad w \in 0^*$

$\# = 1$

1a-2) A TM $t = (Q, \Sigma, \Gamma, \delta, q_0, q_a, q_r)$

Q – a finite set of states

Σ – an alphabet

Γ – an alphabet $\quad \Sigma \subset \Gamma$

$\sqcup \in \Gamma \quad \sqcup \notin \Sigma$

$q_0, q_a, q_r \in Q$ – start, accept, reject

$$\delta : \underbrace{Q}_{Q - \{q_a, q_r\}} \times \Gamma \to Q \times \Gamma \times \{L, R\}$$

$$\text{config} : \underbrace{\Gamma^*}_{\text{left}} \times Q \times \underbrace{\Gamma^*}_{\text{right}} = C$$

14-3/ $w \in L(t)$ iff

$$\varepsilon\,[q_0]\,w \Rightarrow^* x\,[q_a]\,y \qquad x, y \in \Gamma^*$$

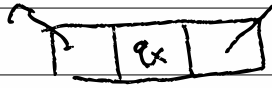
$$\frac{}{x\,[q_i]\,y \Rightarrow \sqcup x\,[q_i]\,y \sqcup}$$

$$\frac{\delta(q_i, a) = (q_j, b, R)}{x\,[q_i]\,ay \Rightarrow x\,b\,[q_j]\,y} \qquad \frac{\delta(q_i, a) = (q_j, b, L)}{xc\,[q_i]\,ay \Rightarrow x\,[q_j]\,cby}$$

```
step : config → config
step (tl, qi, tr) = (tl', qj, tr')
  where (a, y) = look tr
        (qj, b, d) = δ(qi, a)
        (tl', tr') = case d of R → ((b:tl), y)
                               L → (x, c:b:y)
look : List char → (char, list(char))   where (B, x) = look-tl
look ε = (⊔, ε)
look (a:x) = (a, x)
```

$$G\,11\,[q_x]\,101$$

$$\varepsilon \leftarrow 0 \leftarrow 1 \leftarrow 1 \rightarrow 1 \rightarrow 0 \rightarrow 1 \rightarrow \varepsilon$$



19-4/ A computable function

f

is a Turing machine.

And

$$f(x) = y$$

iff

$$\varepsilon [q_0] x \Rightarrow^* w [q_a] y$$

add 1 $\quad 0 = 1 \qquad f(0^x + 0^y) = 0^{x+y}$

$1 = \underline{1}\,0$

$10 = 11$

...

19-5/ When we run a DFA on input w, how long could it take to accept or reject?

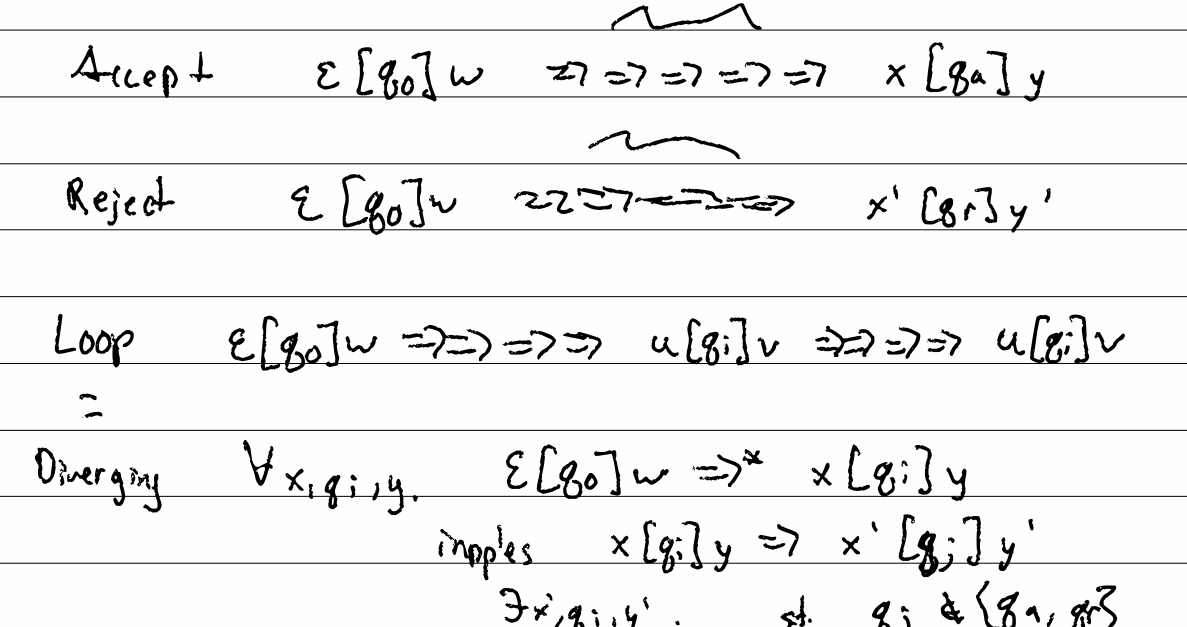
$|w|$ steps $\Rightarrow$ Yes or No

When we run a PDA?

$2^{|w|}$ steps $\Rightarrow$ Yes or No

or running forever $\Rightarrow$ No

19-6 How long does a TM take?



19-7/ A TM is either

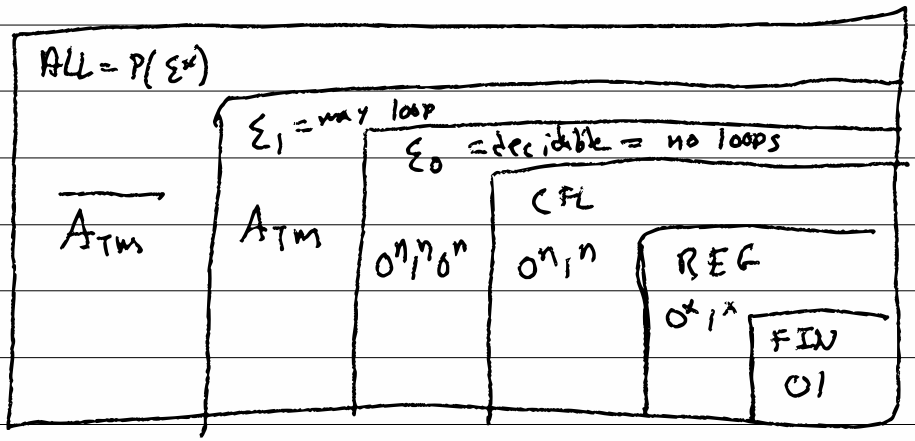
recognizer — may LOOP on some input

decider — never LOOP

a language A_1 is T-recognizable (Σ_1)
$\exists$ m recognizer, $L(m) = A$

T-decidable (Σ_0)
$L(m) = B$

19-8/


ALL = P(Σ*)
Σ1 = may loop
Σ0 = decidable = no loops
CFL
REG
FIN
$\overline{A_{TM}}$
A_{TM}
$0^n1^n0^n$
0^n1^n
0^*1^*
01