- Turing machine w/ a stay option.
  (i.e. the transition function now ~~~~ is

$$\delta : Q \times \Gamma \longrightarrow Q \times \Gamma \times \{L, R, S\}$$

(w/ the relevant def'n of how instant. descr. are affected by S)

- Turing machines w/ multiple tapes (one head)
- Turing machines w/ multiple heads
  - there is a complicated way to simulate w/ a standard TM.

Nondet-TM

$$(q_0, \square) \longrightarrow (q_0, \square, L)$$
$$(q_0, \square) \longrightarrow (q_0, \square, R)$$

(The stupidest non-det TM possible)

<u>Def</u>: A non-det TM accepts a string w if <u>any</u> of the sequences of transitions allowed leads to halting in a final state.

Construct a TM that multiplies its input by 3.

E.g. $\overset{q_0}{\downarrow}$

... □ # 1 1 1 □ □ ...

~~x y 1 y y~~

~~find~~

~~x 1 1 y y y~~

x 1 1 y y

x x 1 y y y y

x x x y y y y y y

□ □ 1 1 1 1 1 1 1 1 1 □ □ ...

change to all 1's.

Closure properties of CF langs

If L_1 & L_2 are CF langs:

$L_1 \cup L_2$ is CF

$L_1 L_2$ is CF

L_1^* is CF

$L_1 \cap L_2$ is not in general CF
(but $L_1 \cap L_2$ is CF if
L_1 is CF
L_2 is reg)

$\overline{L_1}$ is not CF

Eg. $L_1 = \{a^n b^n c^m \mid \text{any } n, m\}$
$L_2 = \{a^m b^n c^n \mid \text{any } n, m\}$

~~$\overline{L_1}$ is not in general CF~~

~~D~~

Problem: P

Input: TMs $M_{\cancel{E}}$ + N

Output: Y if $L(M) = L(N)$

N otherwise

Why is this undecidable?

Assume there is a TM $\dot{P}$ that solves P.

use P to solve Halting Problem:

Input A TM

w string

① ~~change~~ modify A so that it accepts whenever it halts (by making every state final - or ~~makin~~ changing all halting transitions to go to a special final state)

(2) Take A and modify it to A_w so that

~~it~~

if a) ~~first check if the input string is w~~

b) ~~If no, reject; if yes,~~ run A (on w), no matter what input is, accepting on halting.

So ~~A_w~~ - if A halts on w,

$L(A_w) = \cancel{\{w\}}$ every string

If A doesn't halt on w,

$L(A_w) = \emptyset$.

(3) Make a TM $\overline{W}$ that accepts ~~only w,~~ every string

(4) Feed $\overline{W}$ and A_w to P.