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W każdym zadaniu w którym trzeba posługiwać się alfabetem unarnym używam alfabetu **unarnego z zerem**

Maszyny Turinga obliczające funkcje w alfabecie unarnym

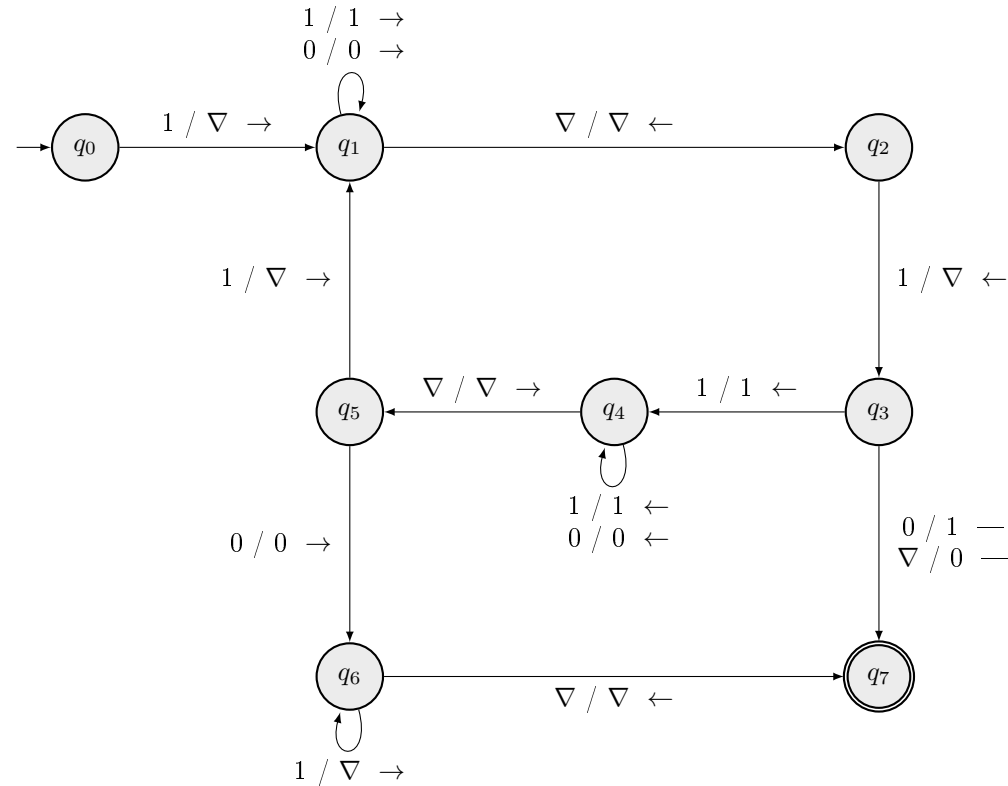
1.1 Zadanie 1.1

Zaprojektuj maszynę Turinga, które oblicza funkcję odejmowania ograniczonego f dla liczb naturalnych m i n w reprezentacji unarnej, czyli

$$(1) \quad f(m, n) = m - n = \begin{cases} m - n, & \text{jeżeli } m \geq n, \\ 0, & \text{jeżeli } m < n \end{cases}$$

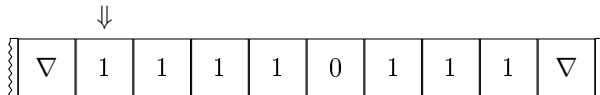
Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(2) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6, q_7\}, \{1, 0\}, \{1, 0, \nabla\}, \delta, q_0, \nabla, \{q_7\})$$



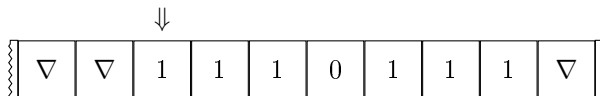
1.1.1 $f(3,2)$

1.



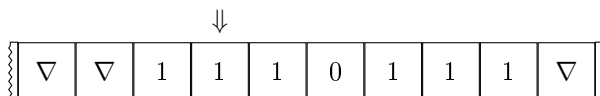
$K_0 \quad q_0 11110111 \vdash$

2.



$K_1 \quad q_1 1110111 \vdash$

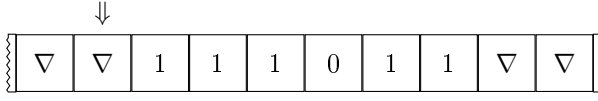
3.



$K_2 \quad 1q_1 110111 \vdash$

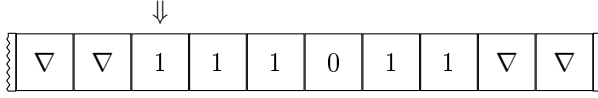
4.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_3 \quad 11q_110111 \vdash$
5.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_4 \quad 111q_10111 \vdash$
6.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_5 \quad 1110q_1111 \vdash$
7.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_6 \quad 11101q_111 \vdash$
8.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_7 \quad 111011q_11 \vdash$
9.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_8 \quad 1110111q_1\nabla \vdash$
10.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_9 \quad 111011q_21 \vdash$
11.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{10} \quad 11101q_31 \vdash$
12.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{11} \quad 1110q_411 \vdash$
13.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{12} \quad 111q_4011 \vdash$
14.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{13} \quad 11q_41011 \vdash$
15.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{14} \quad 1q_411011 \vdash$
16.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{15} \quad q_4111011 \vdash$

17.



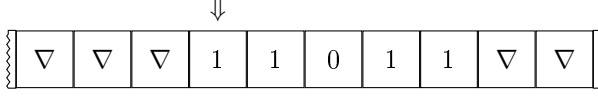
$$K_{16} \quad q_4 \nabla 111011 \vdash$$

18.



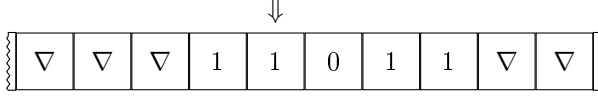
$$K_{17} \quad q_5 111011 \vdash$$

19.



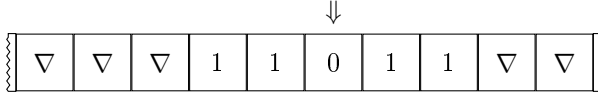
$$K_{18} \quad q_1 11011 \vdash$$

20.



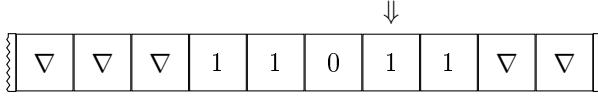
$$K_{19} \quad 1q_1 1011 \vdash$$

21.



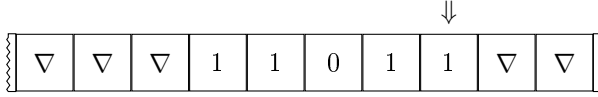
$$K_{20} \quad 11q_1 011 \vdash$$

22.



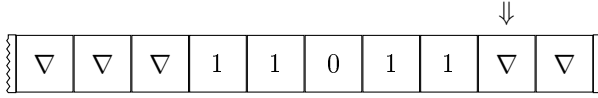
$$K_{21} \quad 110q_1 11 \vdash$$

23.



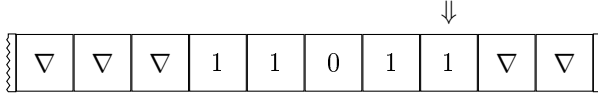
$$K_{22} \quad 1101q_1 1 \vdash$$

24.



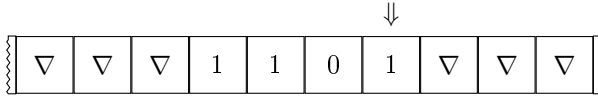
$$K_{23} \quad 11011q_1 \nabla \vdash$$

25.



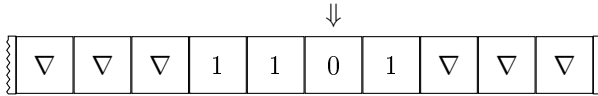
$$K_{24} \quad 1101q_2 1 \vdash$$

26.



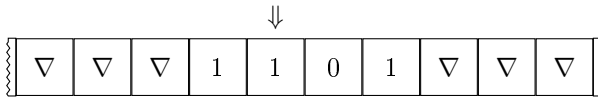
$$K_{25} \quad 110q_3 1 \vdash$$

27.



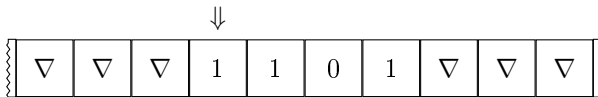
$$K_{26} \quad 11q_4 01 \vdash$$

28.



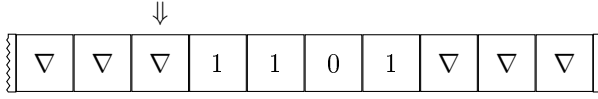
$$K_{27} \quad 1q_4 101 \vdash$$

29.



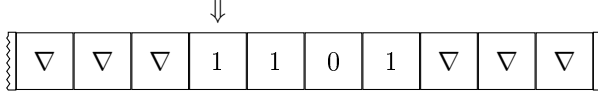
$$K_{28} \quad q_4 1101 \vdash$$

30.



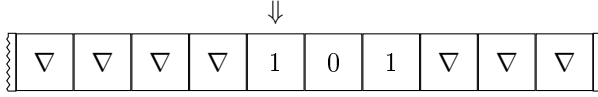
$$K_{29} \quad q_4 \nabla 1101 \vdash$$

31.



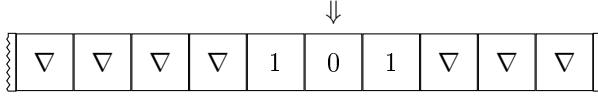
$$K_{30} \quad q_5 1101 \vdash$$

32.



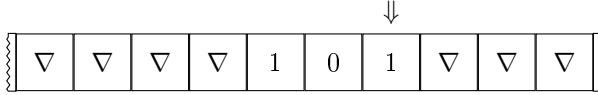
$$K_{31} \quad q_1 101 \vdash$$

33.



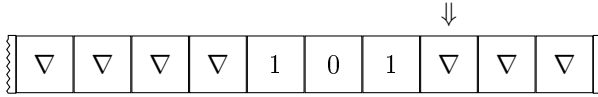
$$K_{32} \quad 1q_1 01 \vdash$$

34.



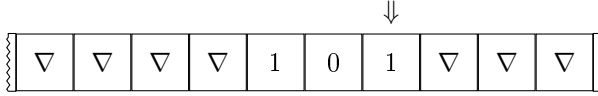
$$K_{33} \quad 10q_1 1 \vdash$$

35.



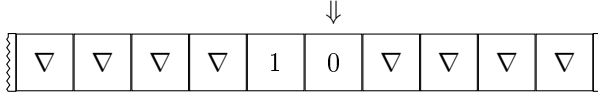
$$K_{34} \quad 101q_1 \nabla \vdash$$

36.



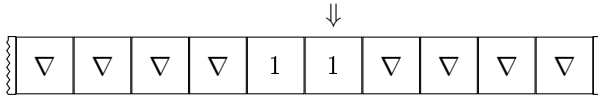
$$K_{35} \quad 10q_2 1 \vdash$$

37.



$$K_{36} \quad 1q_3 0 \vdash$$

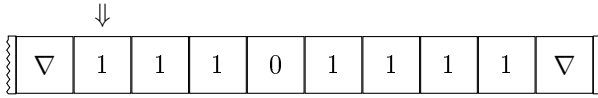
38.



$$K_{37} \quad 1q_7 1$$

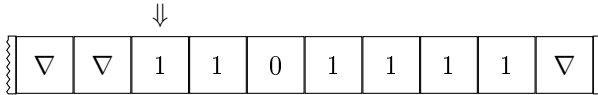
1.1.2 f(2, 3)

1.



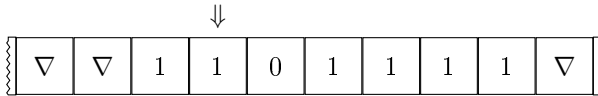
$$K_0 \quad q_0 11101111 \vdash$$

2.



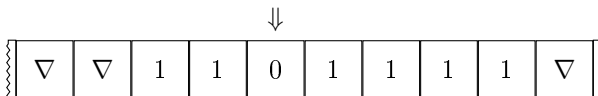
$$K_1 \quad q_1 1101111 \vdash$$

3.



$$K_2 \quad 1q_1 101111 \vdash$$

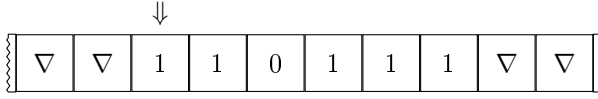
4.



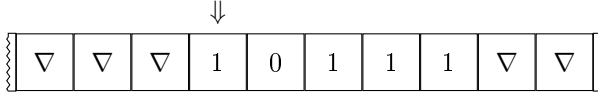
$$K_3 \quad 11q_1 01111 \vdash$$

5.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_4 \quad 110q_11111 \vdash$
6.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_5 \quad 1101q_1111 \vdash$
7.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_6 \quad 11011q_111 \vdash$
8.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_7 \quad 110111q_11 \vdash$
9.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_8 \quad 1101111q_1\nabla \vdash$
10.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_9 \quad 1101111q_21 \vdash$
11.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{10} \quad 11011q_31 \vdash$
12.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{11} \quad 1101q_411 \vdash$
13.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{12} \quad 110q_4111 \vdash$
14.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{13} \quad 11q_40111 \vdash$
15.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{14} \quad 1q_410111 \vdash$
16.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{15} \quad q_4110111 \vdash$
17.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">1</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{16} \quad q_4\nabla110111 \vdash$

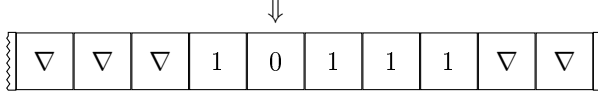
18.

 $K_{17} \quad q_5 110111 \vdash$

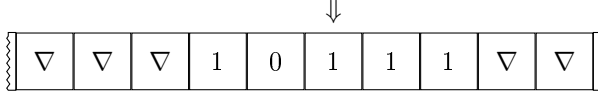
19.

 $K_{18} \quad q_1 10111 \vdash$

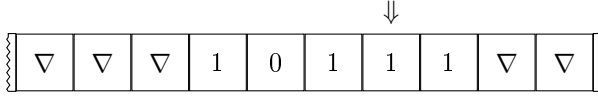
20.

 $K_{19} \quad 1q_1 0111 \vdash$

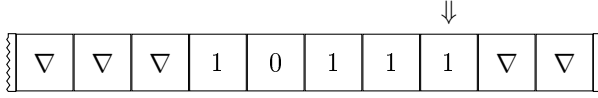
21.

 $K_{20} \quad 10q_1 111 \vdash$

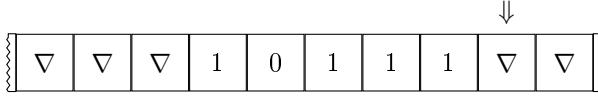
22.

 $K_{21} \quad 101q_1 11 \vdash$

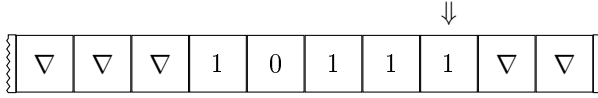
23.

 $K_{22} \quad 1011q_1 1 \vdash$

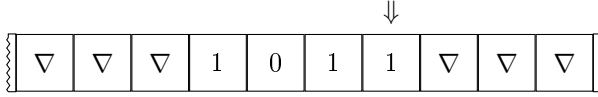
24.

 $K_{23} \quad 10111q_1 \nabla \vdash$

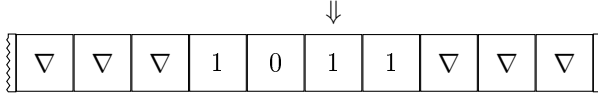
25.

 $K_{24} \quad 1011q_2 1 \vdash$

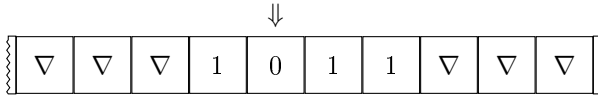
26.

 $K_{25} \quad 101q_3 1 \vdash$

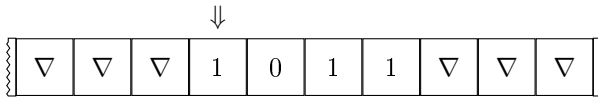
27.

 $K_{26} \quad 10q_4 11 \vdash$

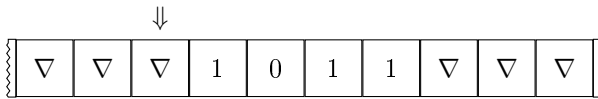
28.

 $K_{27} \quad 1q_4 011 \vdash$

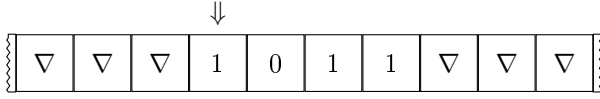
29.

 $K_{28} \quad q_4 1011 \vdash$

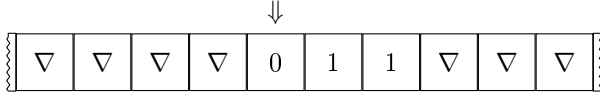
30.

 $K_{29} \quad q_4 \nabla 1011 \vdash$

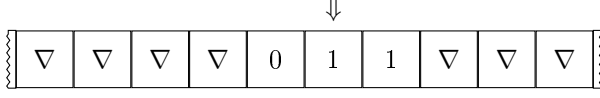
31.

 $K_{30} \quad q_5 1011 \vdash$

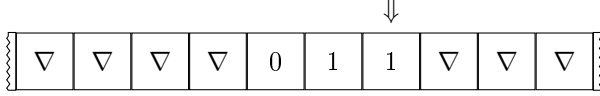
32.

 $K_{31} \quad q_1 011 \vdash$

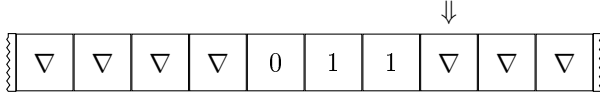
33.

 $K_{32} \quad 0q_1 11 \vdash$

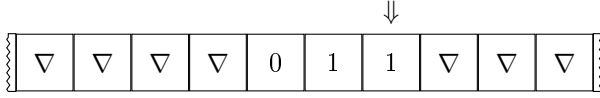
34.

 $K_{33} \quad 01q_1 1 \vdash$

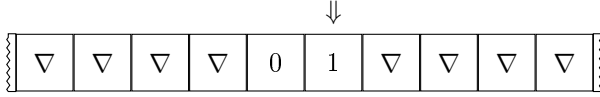
35.

 $K_{34} \quad 011q_1 \nabla \vdash$

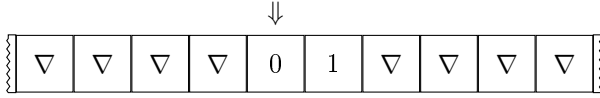
36.

 $K_{35} \quad 01q_2 1 \vdash$

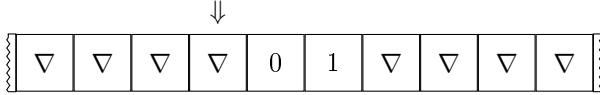
37.

 $K_{36} \quad 0q_3 1 \vdash$

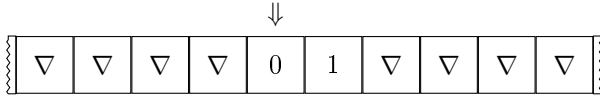
38.

 $K_{37} \quad q_4 01 \vdash$

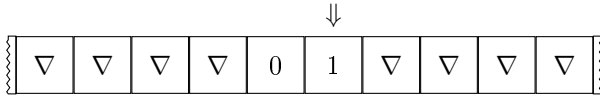
39.

 $K_{38} \quad q_4 \nabla 01 \vdash$

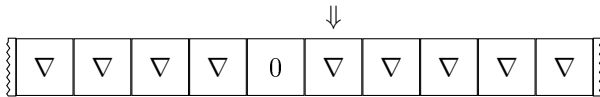
40.

 $K_{39} \quad q_5 01 \vdash$

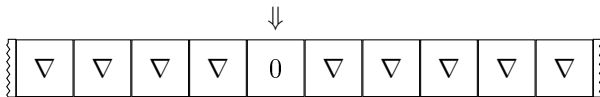
41.

 $K_{40} \quad 0q_6 1 \vdash$

42.

 $K_{41} \quad 0q_6 \nabla \vdash$

43.

 $K_{42} \quad q_7 0$

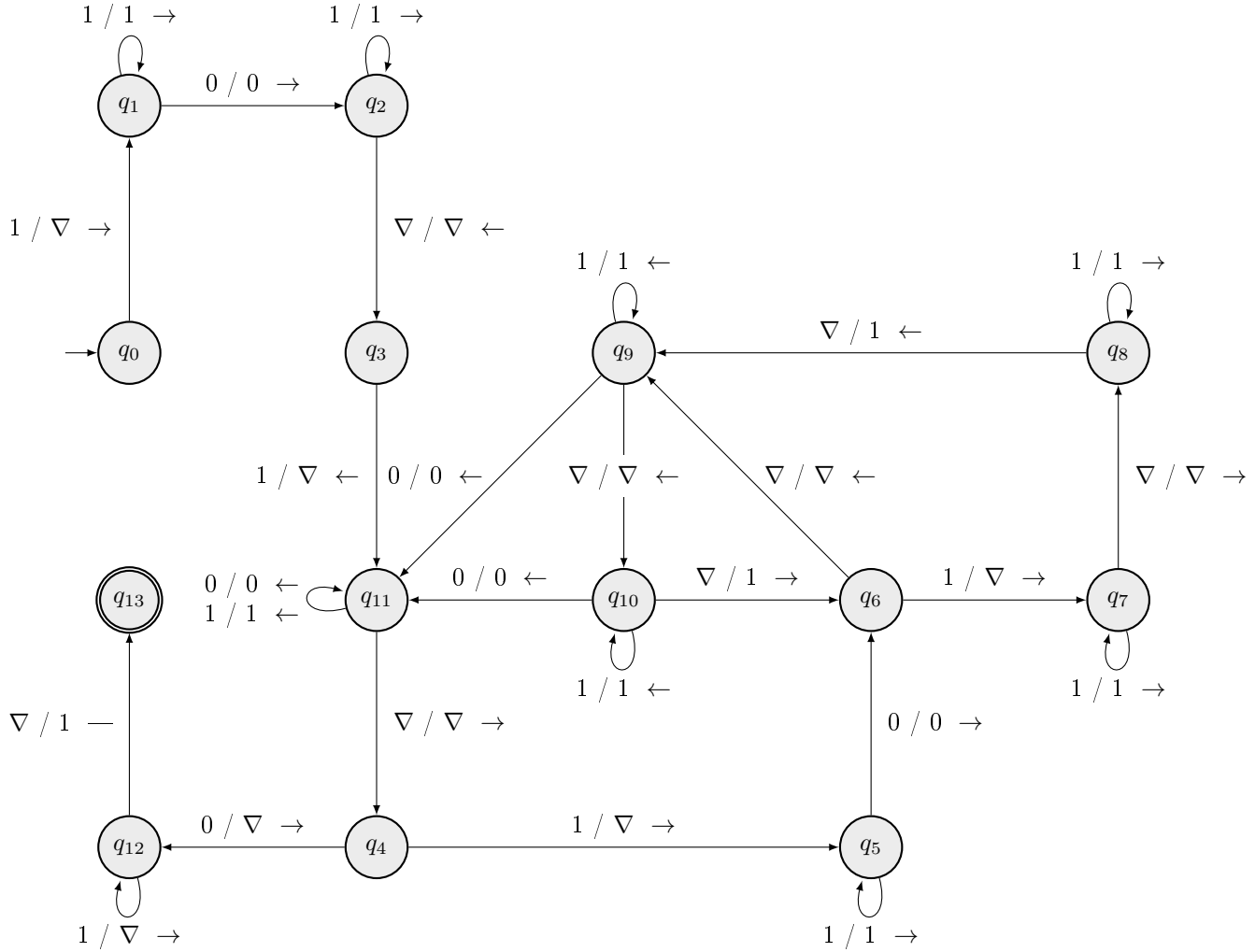
1.2 Zadanie 1.2

Zaprojektuj maszynę Turinga, które oblicza funkcję mnożenia f dla liczb naturalnych m i n w reprezentacji unarnej, czyli

$$(3) \quad f(m, n) = m \cdot n$$

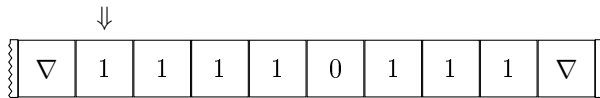
Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia, w tym pomnóż $3 \cdot 2$ lub $2 \cdot 3$ (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(4) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_8, q_9, q_{10}, q_{11}, q_{12}, q_{13}\}, \{1, 0\}, \{1, 0, \nabla\}, \delta, q_0, \nabla, \{q_{13}\})$$



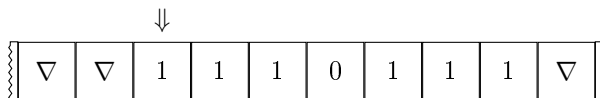
1.2.1 $f(3, 2)$

1.



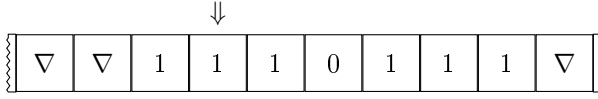
$K_0 \quad q_0 11110111 \vdash$

2.



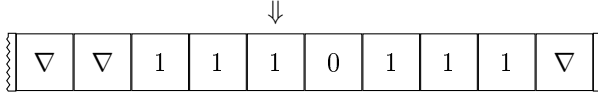
$K_1 \quad q_1 1110111 \vdash$

3.



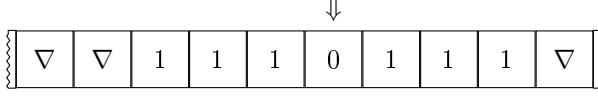
$K_2 \quad 1q_1110111 \vdash$

4.



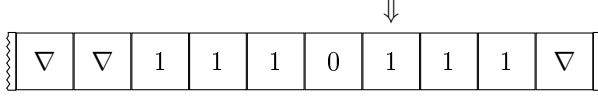
$K_3 \quad 11q_110111 \vdash$

5.



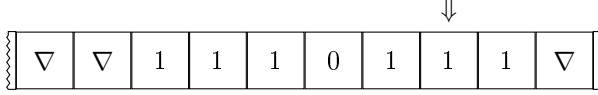
$K_4 \quad 111q_10111 \vdash$

6.



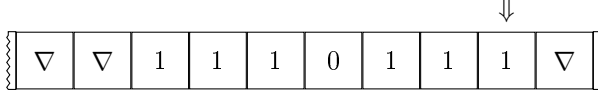
$K_5 \quad 1110q_2111 \vdash$

7.



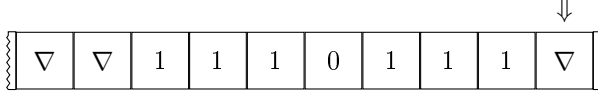
$K_6 \quad 11101q_211 \vdash$

8.



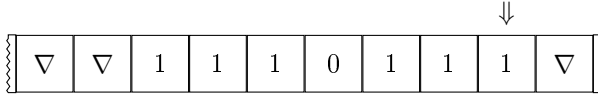
$K_7 \quad 111011q_21 \vdash$

9.



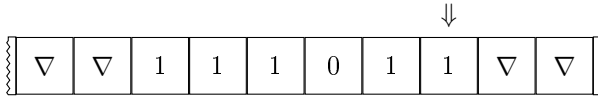
$K_8 \quad 1110111q_2\nabla \vdash$

10.



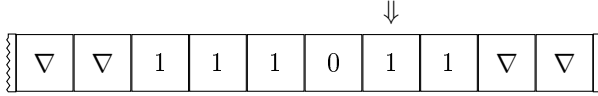
$K_9 \quad 111011q_31 \vdash$

11.



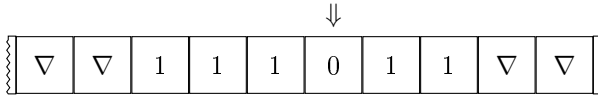
$K_{10} \quad 11101q_{11}1 \vdash$

12.



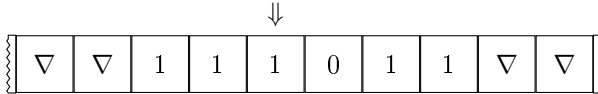
$K_{11} \quad 1110q_{11}11 \vdash$

13.



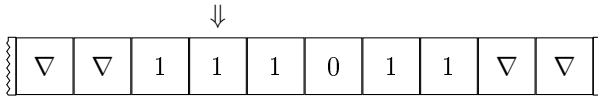
$K_{12} \quad 111q_{11}011 \vdash$

14.



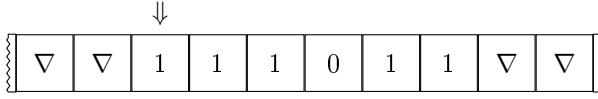
$K_{13} \quad 11q_{11}1011 \vdash$

15.



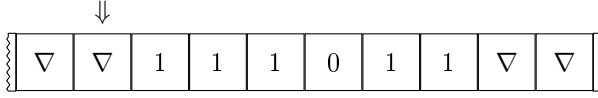
$K_{14} \quad 1q_{11}11011 \vdash$

16.



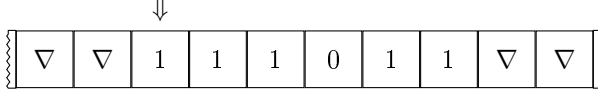
$$K_{15} \quad q_{11}111011 \vdash$$

17.



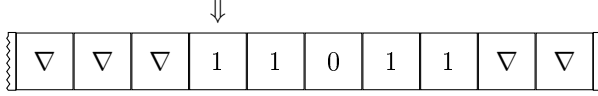
$$K_{16} \quad q_{11}\nabla 111011 \vdash$$

18.



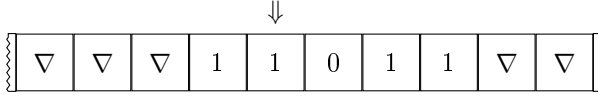
$$K_{17} \quad q_4 111011 \vdash$$

19.



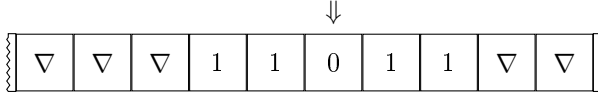
$$K_{18} \quad q_5 11011 \vdash$$

20.



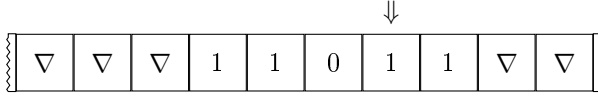
$$K_{19} \quad 1q_5 1011 \vdash$$

21.



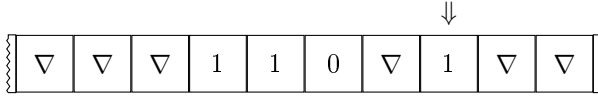
$$K_{20} \quad 11q_5 011 \vdash$$

22.



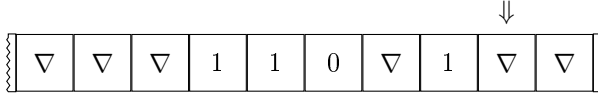
$$K_{21} \quad 110q_6 11 \vdash$$

23.



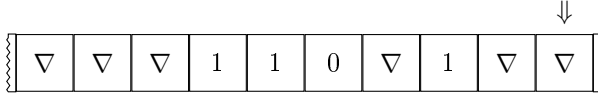
$$K_{22} \quad 110\nabla q_7 1 \vdash$$

24.



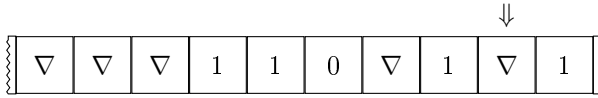
$$K_{23} \quad 110\nabla 1q_7 \nabla \vdash$$

25.



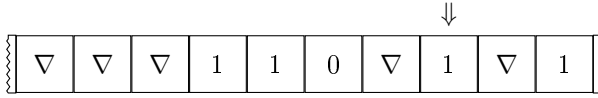
$$K_{24} \quad 110\nabla 1\nabla q_8 \nabla \vdash$$

26.



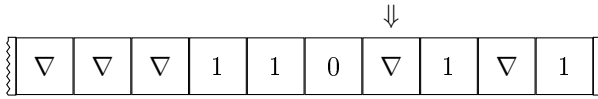
$$K_{25} \quad 110\nabla 1q_9 \nabla 1 \vdash$$

27.



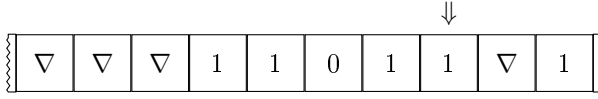
$$K_{26} \quad 110\nabla q_{10} 1 \nabla 1 \vdash$$

28.



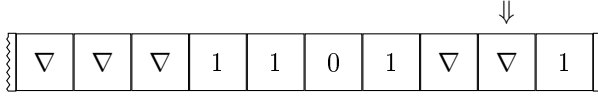
$$K_{27} \quad 110q_{10} \nabla 1 \nabla 1 \vdash$$

29.



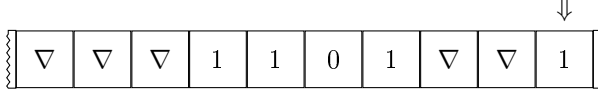
$$K_{28} \quad 1101q_61\nabla 1 \quad \vdash$$

30.



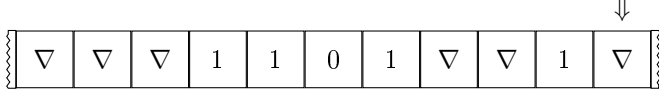
$$K_{29} \quad 1101\nabla q_7\nabla 1 \quad \vdash$$

31.



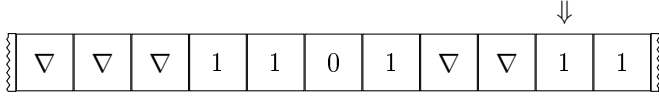
$$K_{30} \quad 1101\nabla\nabla q_81 \quad \vdash$$

32.



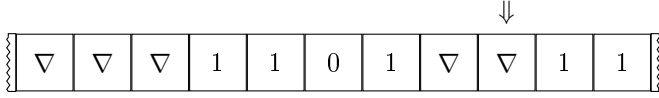
$$K_{31} \quad 1101\nabla\nabla 1q_8\nabla \quad \vdash$$

33.



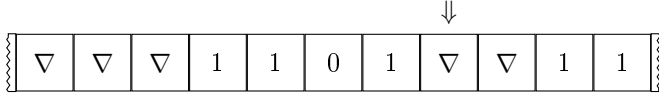
$$K_{32} \quad 1101\nabla\nabla q_911 \quad \vdash$$

34.



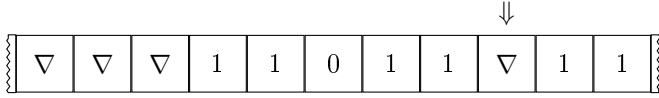
$$K_{33} \quad 1101\nabla q_9\nabla 11 \quad \vdash$$

35.



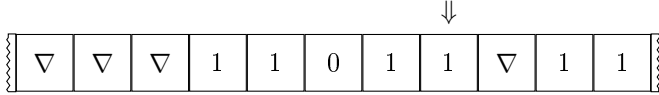
$$K_{34} \quad 1101q_{10}\nabla\nabla 11 \quad \vdash$$

36.



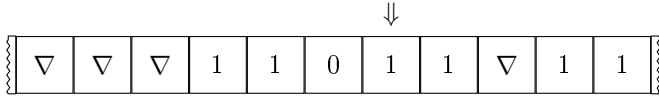
$$K_{35} \quad 11011q_6\nabla 11 \quad \vdash$$

37.



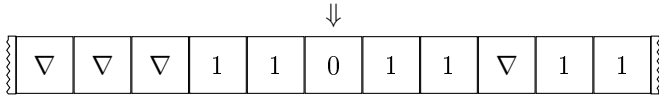
$$K_{36} \quad 1101q_91\nabla 11 \quad \vdash$$

38.



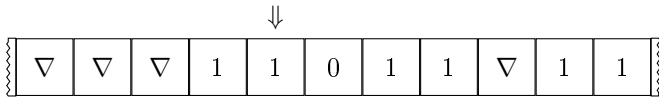
$$K_{37} \quad 110q_911\nabla 11 \quad \vdash$$

39.



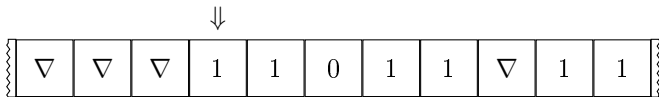
$$K_{38} \quad 11q_9011\nabla 11 \quad \vdash$$

40.



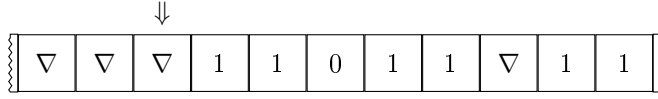
$$K_{39} \quad 1q_{11}1011\nabla 11 \quad \vdash$$

41.



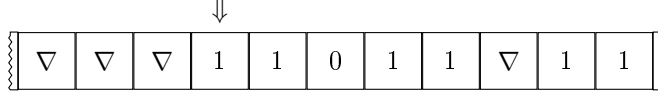
$$K_{40} \quad q_{11}11011\nabla 11 \quad \vdash$$

42.



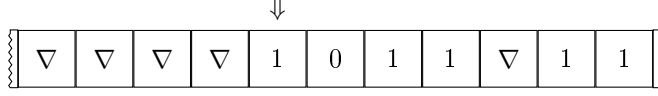
$$K_{41} \quad q_{11} \nabla 11011 \nabla 11 \vdash$$

43.



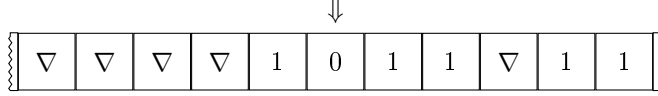
$$K_{42} \quad q_4 11011 \nabla 11 \vdash$$

44.



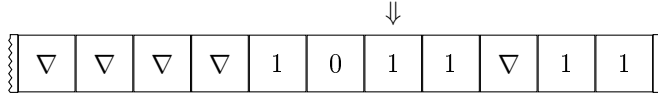
$$K_{43} \quad q_5 1011 \nabla 11 \vdash$$

45.



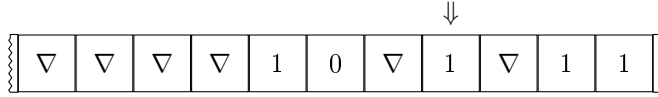
$$K_{44} \quad 1q_5 011 \nabla 11 \vdash$$

46.



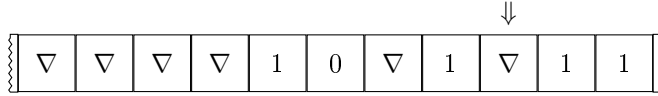
$$K_{45} \quad 10q_6 11 \nabla 11 \vdash$$

47.



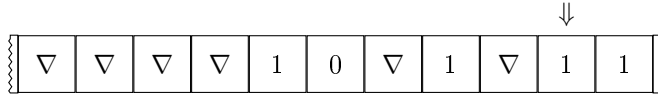
$$K_{46} \quad 10 \nabla q_7 1 \nabla 11 \vdash$$

48.



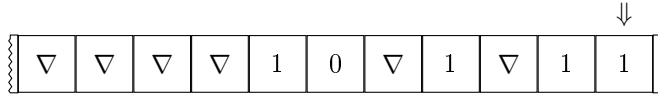
$$K_{47} \quad 10 \nabla 1 q_7 \nabla 11 \vdash$$

49.



$$K_{48} \quad 10 \nabla 1 \nabla q_8 11 \vdash$$

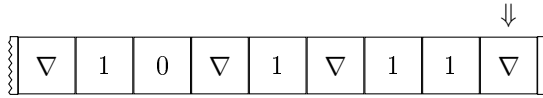
50.



$$K_{49} \quad 10 \nabla 1 \nabla 1 q_8 1 \vdash$$

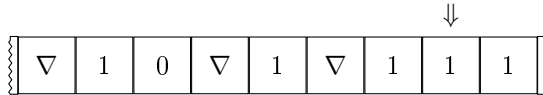
Przesuwam taśmę o 3 miejsca w lewo bo by była zbyt długa

51.



$$K_{50} \quad 10 \nabla 1 \nabla 11 q_8 \nabla \vdash$$

52.



$$K_{51} \quad 10 \nabla 1 \nabla 1 q_9 11 \vdash$$

53.



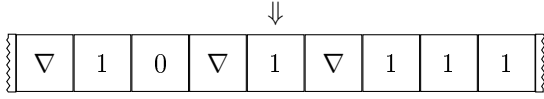
$$K_{52} \quad 10 \nabla 1 \nabla q_9 111 \vdash$$

54.



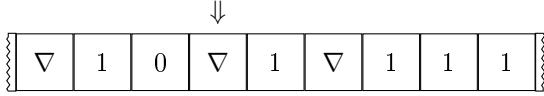
$$K_{53} \quad 10 \nabla 1 q_9 \nabla 111 \vdash$$

55.



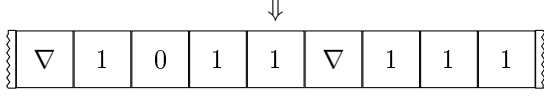
$$K_{54} \quad 10\nabla q_{10}1\nabla111 \vdash$$

56.



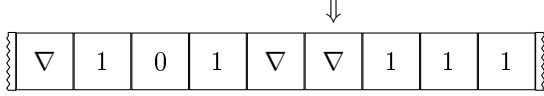
$$K_{55} \quad 10q_{10}\nabla1\nabla111 \vdash$$

57.



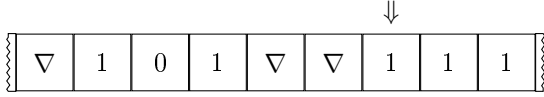
$$K_{56} \quad 101q_61\nabla111 \vdash$$

58.



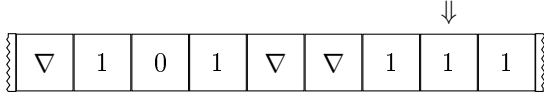
$$K_{57} \quad 101\nabla q_7\nabla111 \vdash$$

59.



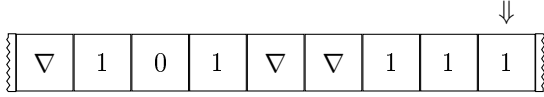
$$K_{58} \quad 101\nabla\nabla q_8111 \vdash$$

60.



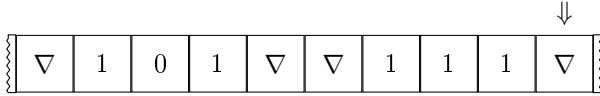
$$K_{59} \quad 101\nabla\nabla1q_811 \vdash$$

61.



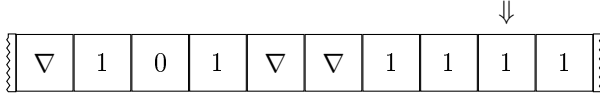
$$K_{60} \quad 101\nabla\nabla11q_81 \vdash$$

62.



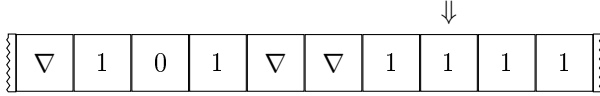
$$K_{61} \quad 101\nabla\nabla111q_8\nabla \vdash$$

63.



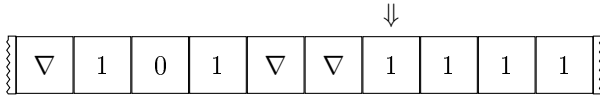
$$K_{62} \quad 101\nabla\nabla11q_911 \vdash$$

64.



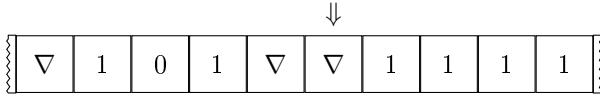
$$K_{63} \quad 101\nabla\nabla1q_9111 \vdash$$

65.



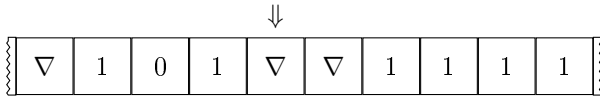
$$K_{64} \quad 101\nabla\nabla q_91111 \vdash$$

66.



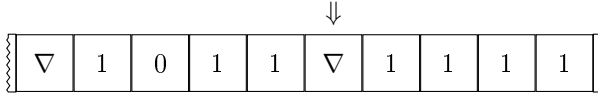
$$K_{65} \quad 101\nabla q_9\nabla1111 \vdash$$

67.



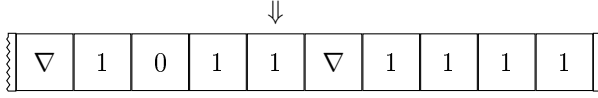
$$K_{66} \quad 101q_{10}\nabla\nabla1111 \vdash$$

68.



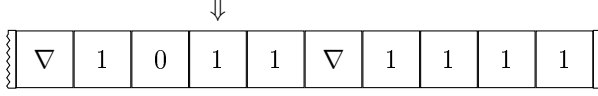
$$K_{67} \quad 1011q_6\nabla 1111 \vdash$$

69.



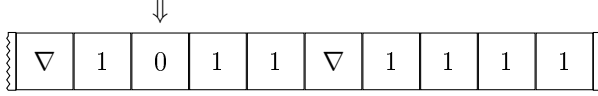
$$K_{68} \quad 101q_91\nabla 1111 \vdash$$

70.



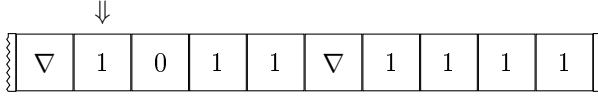
$$K_{69} \quad 10q_911\nabla 1111 \vdash$$

71.



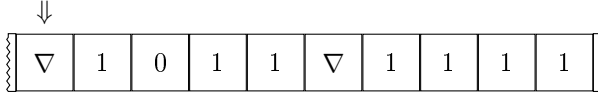
$$K_{70} \quad 1q_9011\nabla 1111 \vdash$$

72.



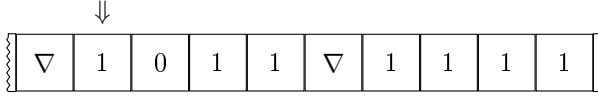
$$K_{71} \quad q_{11}1011\nabla 1111 \vdash$$

73.



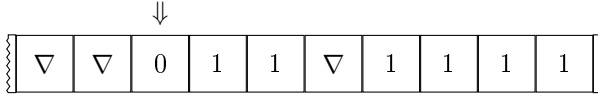
$$K_{72} \quad q_{11}\nabla 1011\nabla 1111 \vdash$$

74.



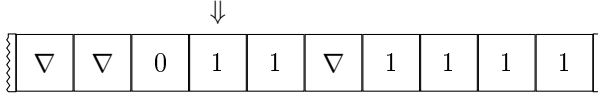
$$K_{73} \quad q_41011\nabla 1111 \vdash$$

75.



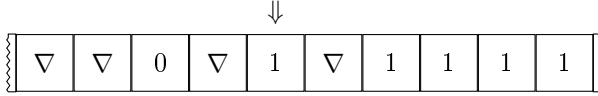
$$K_{74} \quad q_5011\nabla 1111 \vdash$$

76.



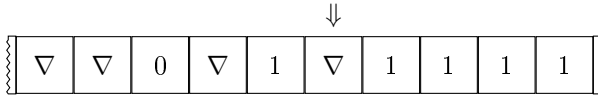
$$K_{75} \quad 0q_611\nabla 1111 \vdash$$

77.



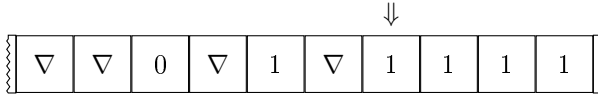
$$K_{76} \quad 0\nabla q_71\nabla 1111 \vdash$$

78.



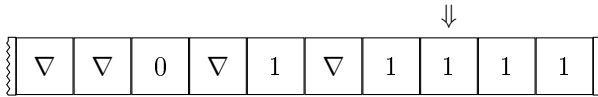
$$K_{77} \quad 0\nabla 1q_7\nabla 1111 \vdash$$

79.



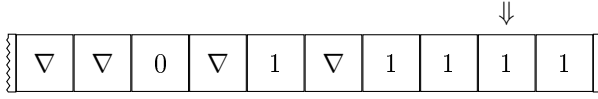
$$K_{78} \quad 0\nabla 1\nabla q_81111 \vdash$$

80.



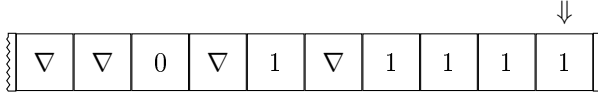
$$K_{79} \quad 0\nabla 1\nabla 1q_8111 \vdash$$

81.



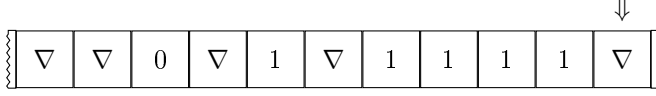
$$K_{80} \quad 0\nabla 1\nabla 11q_8 11 \quad \vdash$$

82.



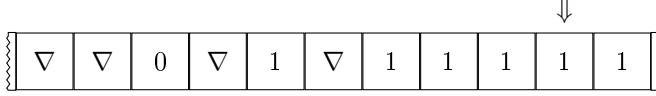
$$K_{81} \quad 0\nabla 1\nabla 111q_8 1 \quad \vdash$$

83.



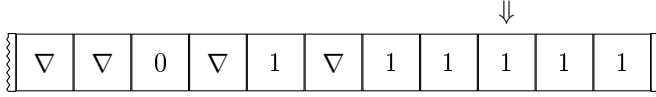
$$K_{82} \quad 0\nabla 1\nabla 1111q_8 \nabla \quad \vdash$$

84.



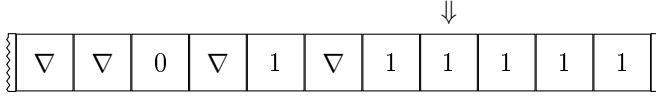
$$K_{83} \quad 0\nabla 1\nabla 111q_9 11 \quad \vdash$$

85.



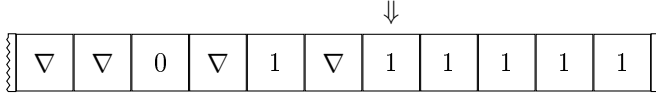
$$K_{84} \quad 0\nabla 1\nabla 11q_9 111 \quad \vdash$$

86.



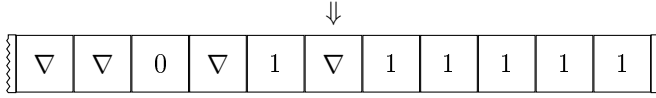
$$K_{85} \quad 0\nabla 1\nabla 1q_9 1111 \quad \vdash$$

87.



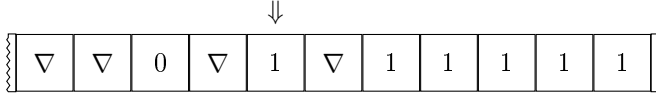
$$K_{86} \quad 0\nabla 1\nabla q_9 11111 \quad \vdash$$

88.



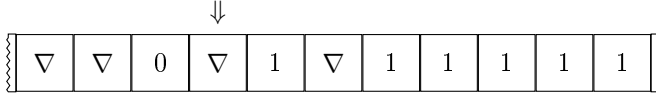
$$K_{87} \quad 0\nabla 1q_9 \nabla 11111 \quad \vdash$$

89.



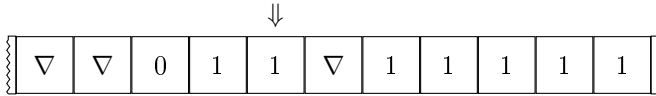
$$K_{88} \quad 0\nabla q_{10} 1\nabla 11111 \quad \vdash$$

90.



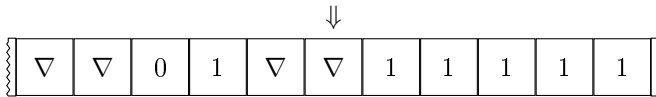
$$K_{89} \quad 0q_{10} \nabla 1\nabla 11111 \quad \vdash$$

91.



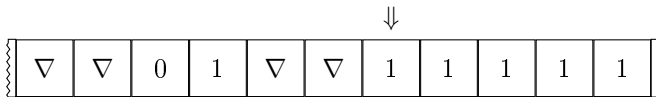
$$K_{90} \quad 01q_6 1\nabla 11111 \quad \vdash$$

92.



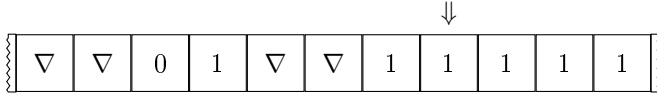
$$K_{91} \quad 01\nabla q_7 \nabla 11111 \quad \vdash$$

93.



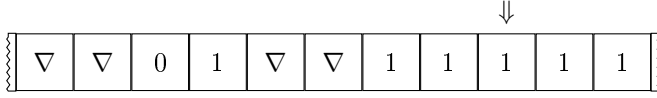
$$K_{92} \quad 01\nabla \nabla q_8 11111 \quad \vdash$$

94.



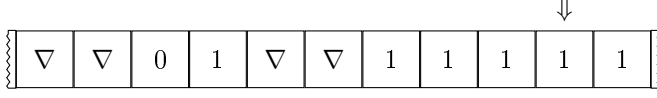
$$K_{93} \quad 01\nabla\nabla 1q_8 1111 \vdash$$

95.



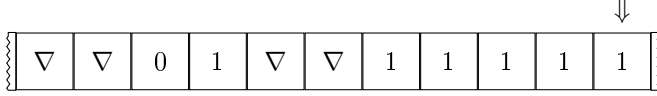
$$K_{94} \quad 01\nabla\nabla 11q_8 111 \vdash$$

96.



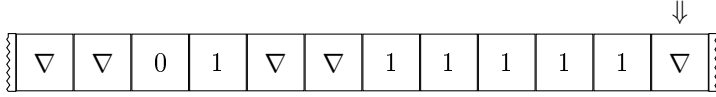
$$K_{95} \quad 01\nabla\nabla 111q_8 11 \vdash$$

97.



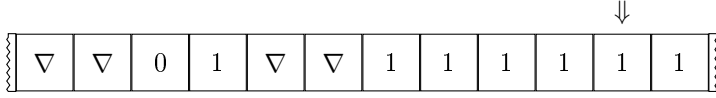
$$K_{96} \quad 01\nabla\nabla 1111q_8 1 \vdash$$

98.



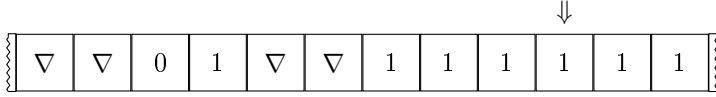
$$K_{97} \quad 01\nabla\nabla 11111q_8 \nabla \vdash$$

99.



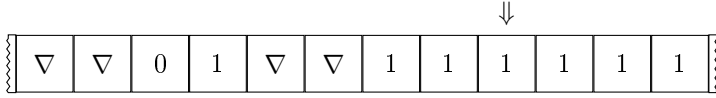
$$K_{98} \quad 01\nabla\nabla 1111q_9 11 \vdash$$

100.



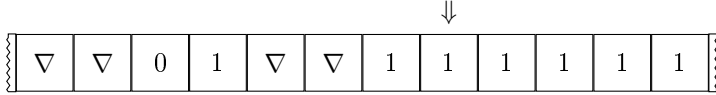
$$K_{99} \quad 01\nabla\nabla 111q_9 111 \vdash$$

101.



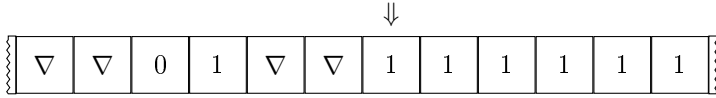
$$K_{100} \quad 01\nabla\nabla 11q_9 1111 \vdash$$

102.



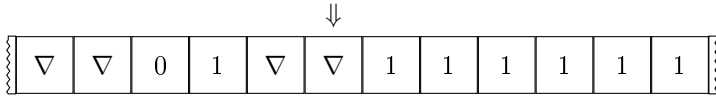
$$K_{101} \quad 01\nabla\nabla 1q_9 11111 \vdash$$

103.



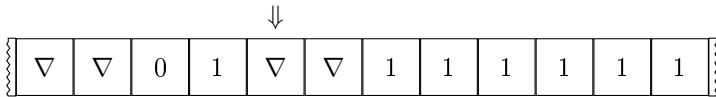
$$K_{102} \quad 01\nabla\nabla q_9 111111 \vdash$$

104.



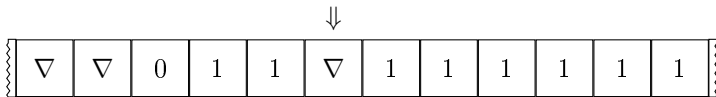
$$K_{103} \quad 01\nabla q_9 \nabla 111111 \vdash$$

105.



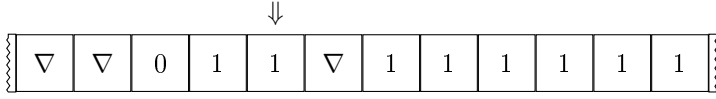
$$K_{104} \quad 01q_{10} \nabla \nabla 111111 \vdash$$

106.



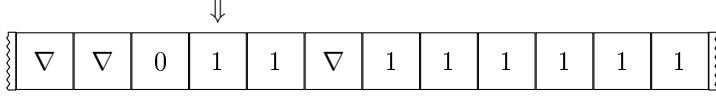
$$K_{105} \quad 011q_6 \nabla 111111 \vdash$$

107.



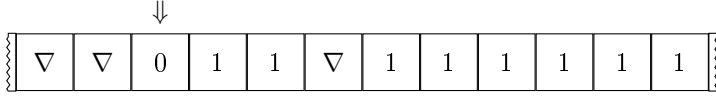
$K_{106} \quad 01q_91\nabla111111 \vdash$

108.



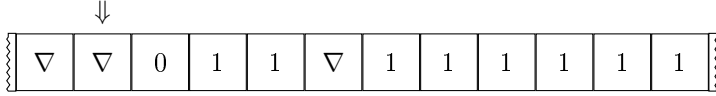
$K_{107} \quad 0q_911\nabla111111 \vdash$

109.



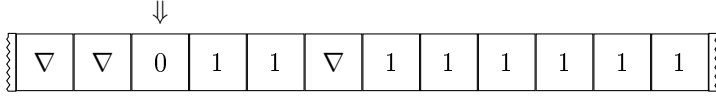
$K_{108} \quad q_9011\nabla111111 \vdash$

110.



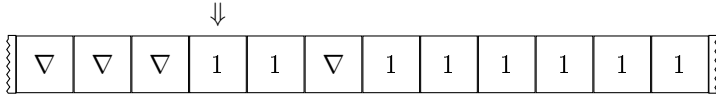
$K_{109} \quad q_{11}\nabla011\nabla111111 \vdash$

111.



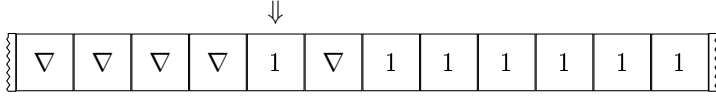
$K_{110} \quad q_4011\nabla111111 \vdash$

112.



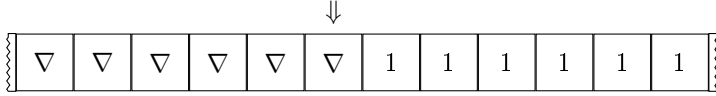
$K_{111} \quad q_{12}11\nabla111111 \vdash$

113.



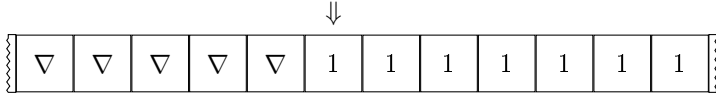
$K_{112} \quad q_{12}1\nabla111111 \vdash$

114.



$K_{113} \quad q_{12}\nabla111111 \vdash$

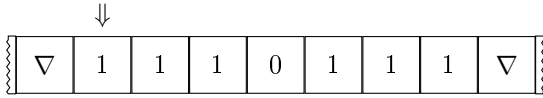
115.



$K_{114} \quad q_{13}1111111$

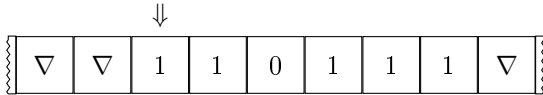
1.2.2 f(2, 2)

1.



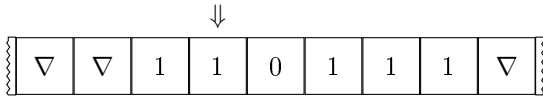
$K_0 \quad q_01110111 \vdash$

2.



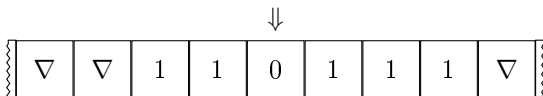
$K_1 \quad q_1110111 \vdash$

3.

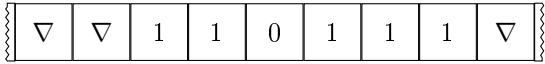
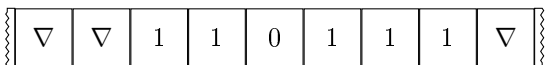
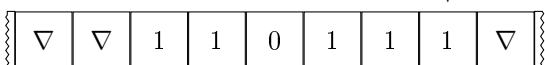
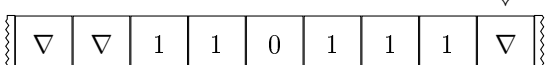
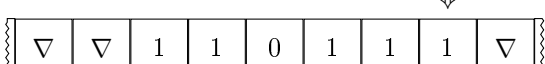
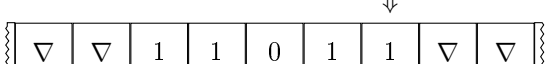
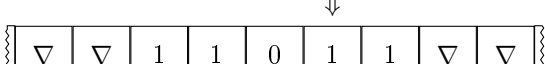
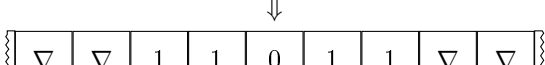
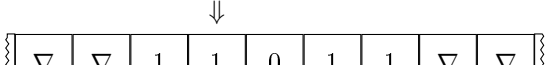
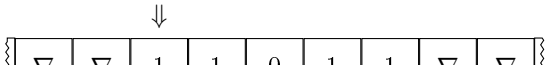
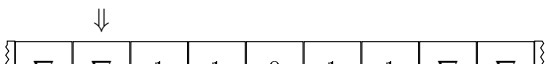
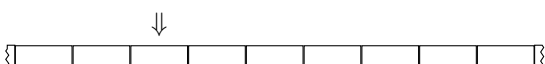
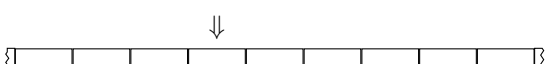


$K_2 \quad 1q_110111 \vdash$

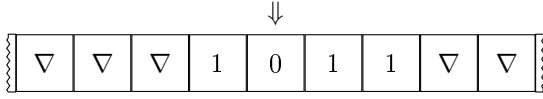
4.



$K_3 \quad 11q_10111 \vdash$

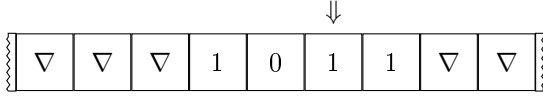
5. \Downarrow

 $K_4 \quad 110q_2111 \vdash$
6. \Downarrow

 $K_5 \quad 1101q_211 \vdash$
7. \Downarrow

 $K_6 \quad 11011q_21 \vdash$
8. \Downarrow

 $K_7 \quad 110111q_2\nabla \vdash$
9. \Downarrow

 $K_8 \quad 11011q_31 \vdash$
10. \Downarrow

 $K_9 \quad 1101q_{11}1 \vdash$
11. \Downarrow

 $K_{10} \quad 110q_{11}11 \vdash$
12. \Downarrow

 $K_{11} \quad 11q_{11}011 \vdash$
13. \Downarrow

 $K_{12} \quad 1q_{11}1011 \vdash$
14. \Downarrow

 $K_{13} \quad q_{11}11011 \vdash$
15. \Downarrow

 $K_{14} \quad q_{11}\nabla 11011 \vdash$
16. \Downarrow

 $K_{15} \quad q_411011 \vdash$
17. \Downarrow

 $K_{16} \quad q_51011 \vdash$

18.



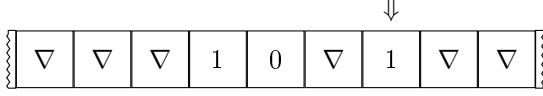
$K_{17} \quad 1q_5 011 \quad \vdash$

19.



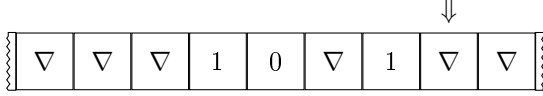
$K_{18} \quad 10q_6 11 \quad \vdash$

20.



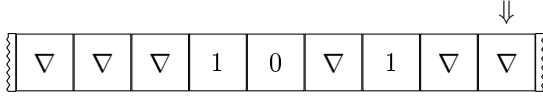
$K_{19} \quad 10\nabla q_7 1 \quad \vdash$

21.



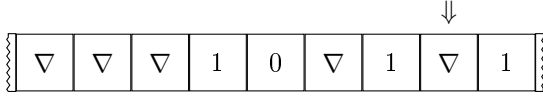
$K_{20} \quad 10\nabla 1q_7 \nabla \quad \vdash$

22.



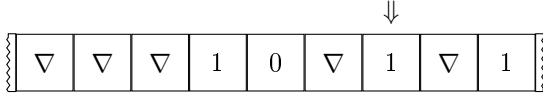
$K_{21} \quad 10\nabla 1\nabla q_8 \nabla \quad \vdash$

23.



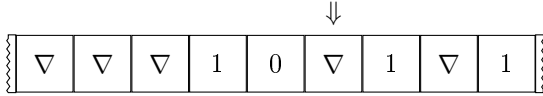
$K_{22} \quad 10\nabla 1q_9 \nabla 1 \quad \vdash$

24.



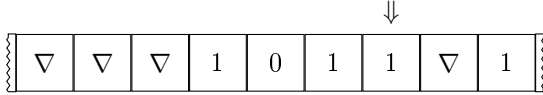
$K_{23} \quad 10\nabla q_{10} 1\nabla 1 \quad \vdash$

25.



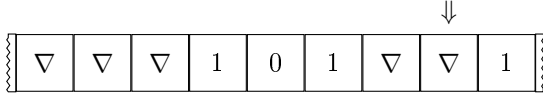
$K_{24} \quad 10q_{10} \nabla 1\nabla 1 \quad \vdash$

26.



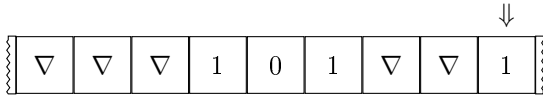
$K_{25} \quad 101q_6 1\nabla 1 \quad \vdash$

27.



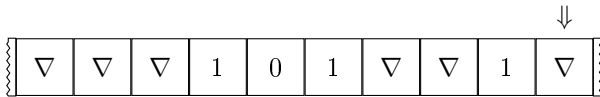
$K_{26} \quad 101\nabla q_7 \nabla 1 \quad \vdash$

28.



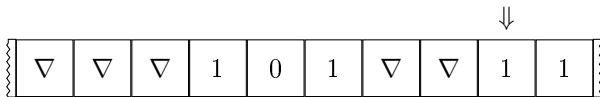
$K_{27} \quad 101\nabla \nabla q_8 1 \quad \vdash$

29.



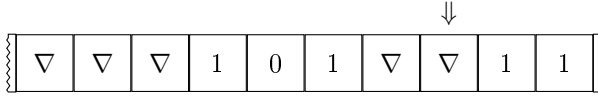
$K_{28} \quad 101\nabla \nabla 1q_8 \nabla \quad \vdash$

30.



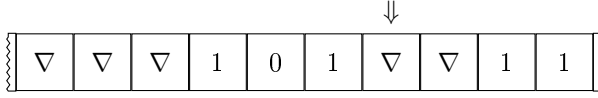
$K_{29} \quad 101\nabla \nabla q_9 11 \quad \vdash$

31.



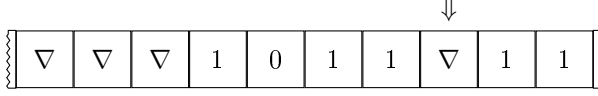
$$K_{30} \quad 101\nabla q_9\nabla 11 \vdash$$

32.



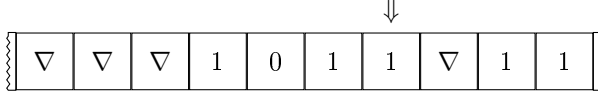
$$K_{31} \quad 101q_{10}\nabla\nabla 11 \vdash$$

33.



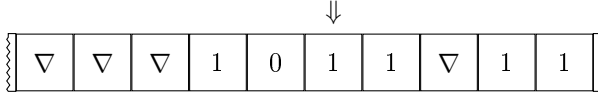
$$K_{32} \quad 1011q_6\nabla 11 \vdash$$

34.



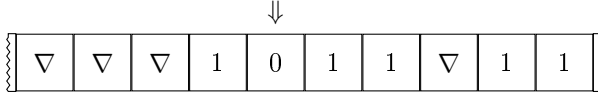
$$K_{33} \quad 101q_91\nabla 11 \vdash$$

35.



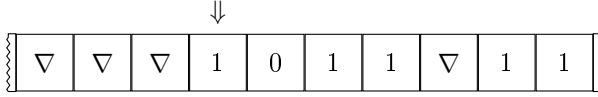
$$K_{34} \quad 10q_911\nabla 11 \vdash$$

36.



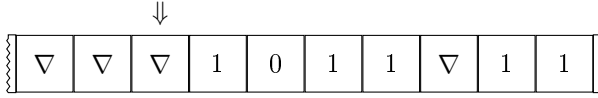
$$K_{35} \quad 1q_9011\nabla 11 \vdash$$

37.



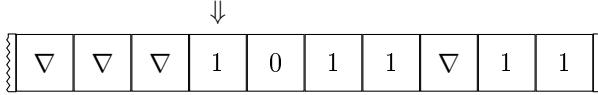
$$K_{36} \quad q_{11}1011\nabla 11 \vdash$$

38.



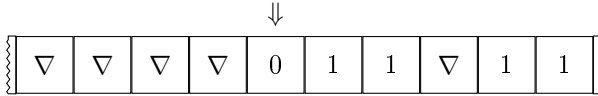
$$K_{37} \quad q_{11}\nabla 1011\nabla 11 \vdash$$

39.



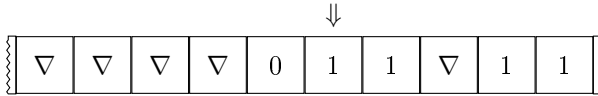
$$K_{38} \quad q_41011\nabla 11 \vdash$$

40.



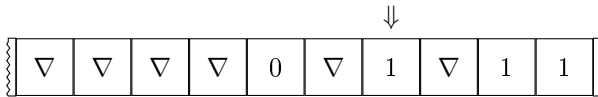
$$K_{39} \quad q_5011\nabla 11 \vdash$$

41.



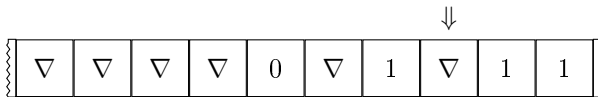
$$K_{40} \quad 0q_611\nabla 11 \vdash$$

42.



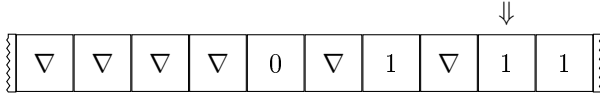
$$K_{41} \quad 0\nabla q_71\nabla 11 \vdash$$

43.



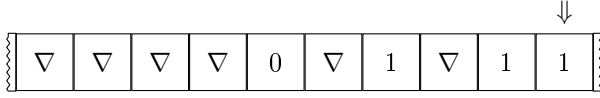
$$K_{42} \quad 0\nabla 1q_7\nabla 11 \vdash$$

44.



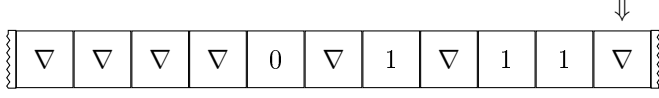
$$K_{43} \quad 0\nabla 1\nabla q_8 11 \vdash$$

45.



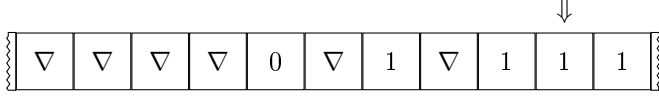
$$K_{44} \quad 0\nabla 1\nabla 1q_8 1 \vdash$$

46.



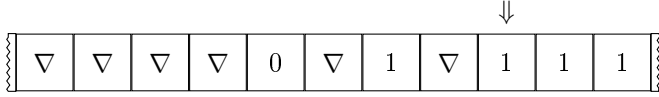
$$K_{45} \quad 0\nabla 1\nabla 11q_8 \nabla \vdash$$

47.



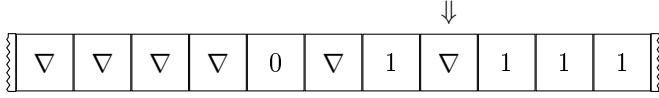
$$K_{46} \quad 0\nabla 1\nabla 1q_9 11 \vdash$$

48.



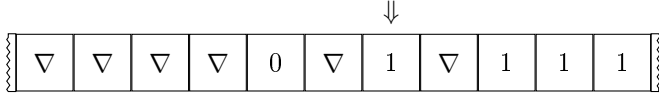
$$K_{47} \quad 0\nabla 1\nabla q_9 111 \vdash$$

49.



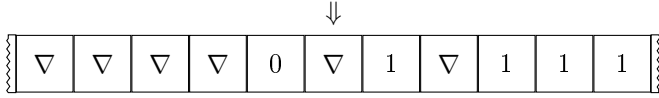
$$K_{48} \quad 0\nabla 1q_9 \nabla 111 \vdash$$

50.



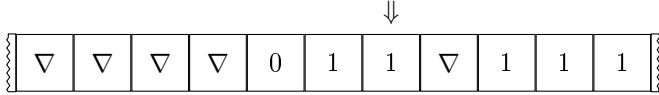
$$K_{49} \quad 0\nabla q_{10} 1\nabla 111 \vdash$$

51.



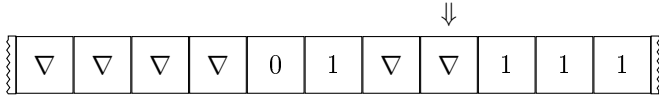
$$K_{50} \quad 0q_{10} \nabla 1\nabla 111 \vdash$$

52.



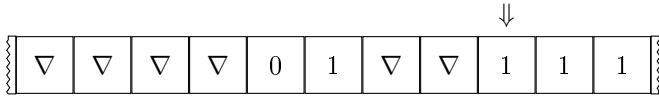
$$K_{51} \quad 01q_6 1\nabla 111 \vdash$$

53.



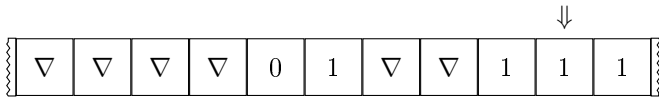
$$K_{52} \quad 01\nabla q_7 \nabla 111 \vdash$$

54.



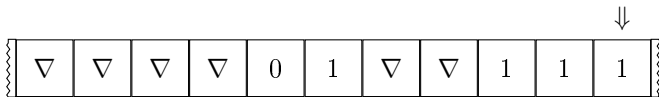
$$K_{53} \quad 01\nabla \nabla q_8 111 \vdash$$

55.



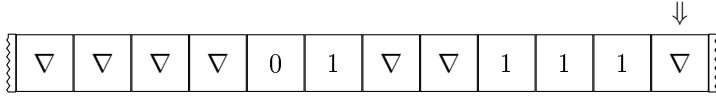
$$K_{54} \quad 01\nabla \nabla 1q_8 11 \vdash$$

56.



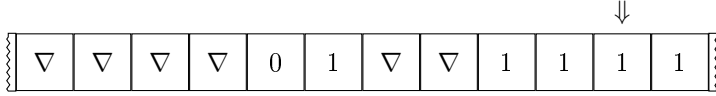
$$K_{55} \quad 01\nabla \nabla 11q_8 1 \vdash$$

57.



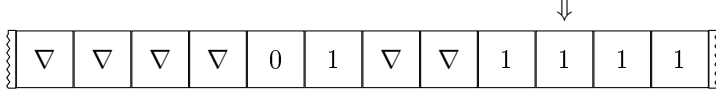
$$K_{56} \quad 01\nabla\nabla111q_8\nabla \vdash$$

58.



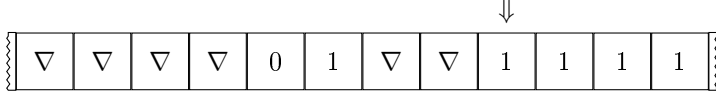
$$K_{57} \quad 01\nabla\nabla11q_911 \vdash$$

59.



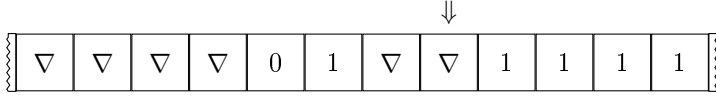
$$K_{58} \quad 01\nabla\nabla1q_9111 \vdash$$

60.



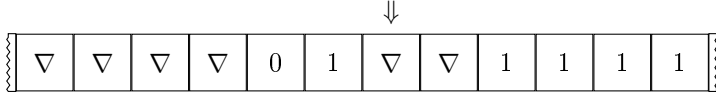
$$K_{59} \quad 01\nabla\nabla q_91111 \vdash$$

61.



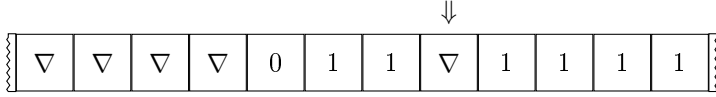
$$K_{60} \quad 01\nabla q_9\nabla1111 \vdash$$

62.



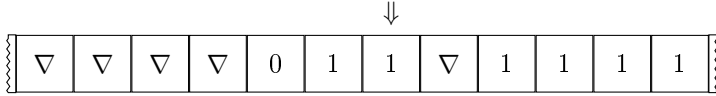
$$K_{61} \quad 01q_{10}\nabla\nabla1111 \vdash$$

63.



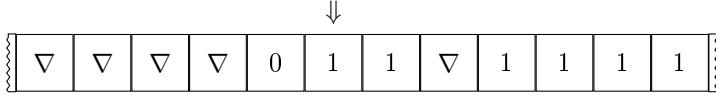
$$K_{62} \quad 011q_6\nabla1111 \vdash$$

64.



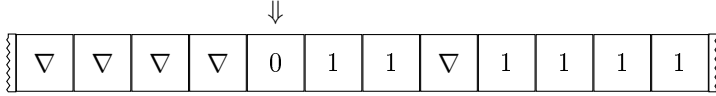
$$K_{63} \quad 01q_91\nabla1111 \vdash$$

65.



$$K_{64} \quad 0q_911\nabla1111 \vdash$$

66.



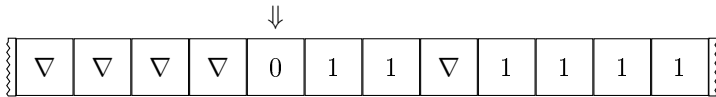
$$K_{65} \quad q_9011\nabla1111 \vdash$$

67.



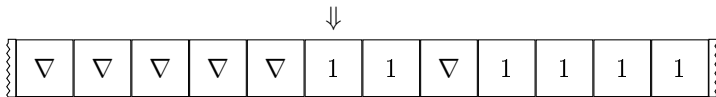
$$K_{66} \quad q_{11}\nabla011\nabla1111 \vdash$$

68.



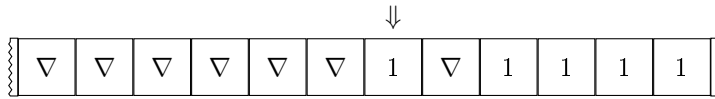
$$K_{67} \quad q_4011\nabla1111 \vdash$$

69.



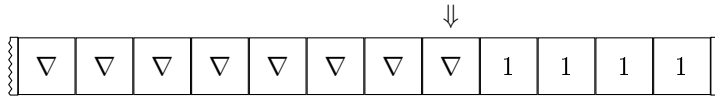
$$K_{68} \quad q_{12}11\nabla1111 \vdash$$

70.



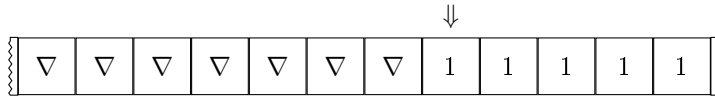
$K_{69} \quad q_{12}1\nabla1111 \vdash$

71.



$K_{70} \quad q_{12}\nabla1111 \vdash$

72.



$K_{71} \quad q_{13}11111$

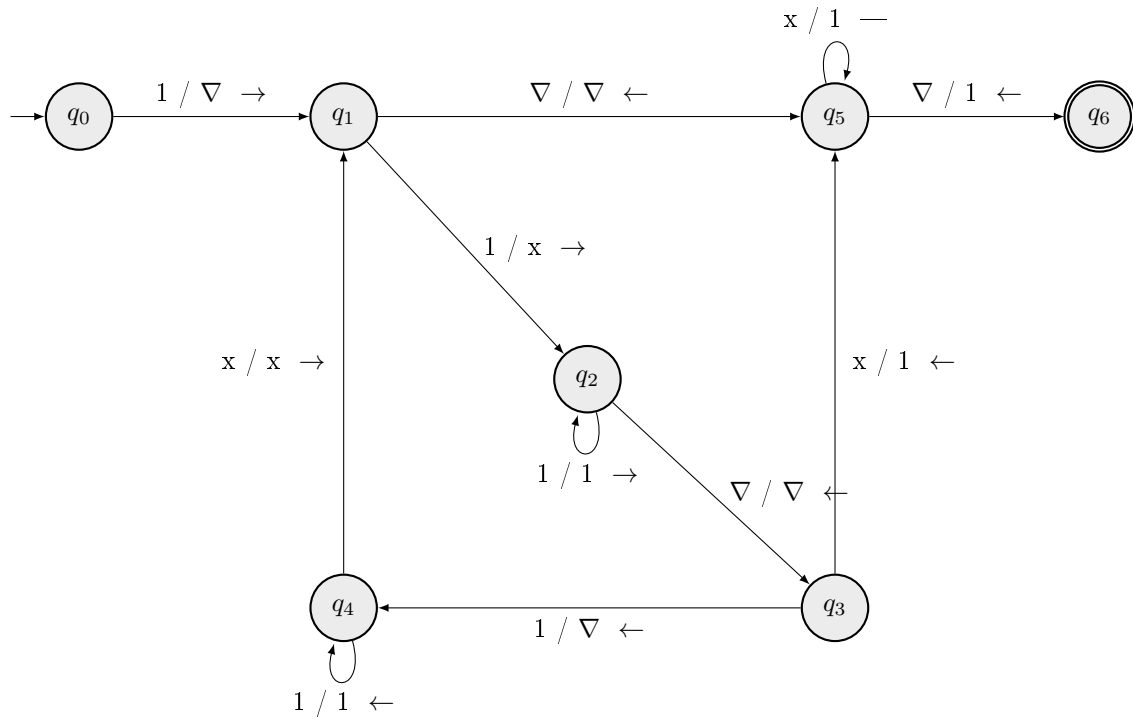
1.3 Zadanie 1.3

Zaprojektuj maszynę Turinga, które oblicza funkcję f dla liczby naturalnej n w reprezentacji unarnej, gdzie

$$(5) \quad f(n) = \begin{cases} \frac{n}{2}, & \text{jeżeli } n \text{ jest parzysta,} \\ \frac{n+1}{2}, & \text{jeżeli } n \text{ jest nieparzysta} \end{cases}$$

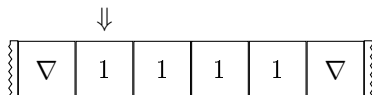
Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(6) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6\}, \{1\}, \{1, x, \nabla\}, \delta, q_0, \nabla, \{q_6\})$$



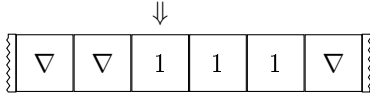
1.3.1 f(3)

1.



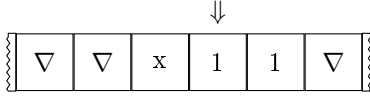
$K_0 \quad q_01111 \vdash$

2.



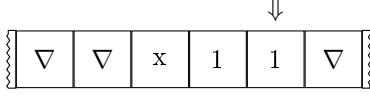
$$K_1 \quad q_1 111 \vdash$$

3.



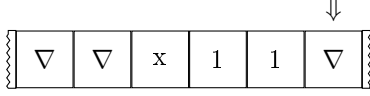
$$K_2 \quad xq_2 11 \vdash$$

4.



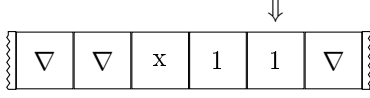
$$K_3 \quad x1q_2 1 \vdash$$

5.



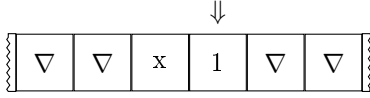
$$K_4 \quad x11q_2 \nabla \vdash$$

6.



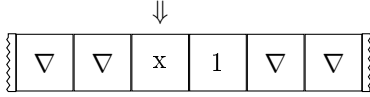
$$K_5 \quad x1q_3 1 \vdash$$

7.



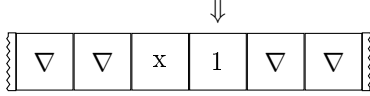
$$K_6 \quad xq_4 1 \vdash$$

8.



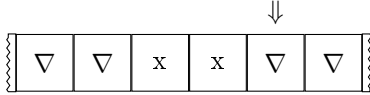
$$K_7 \quad q_4 x1 \vdash$$

9.



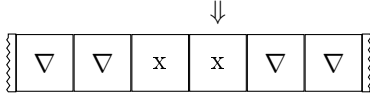
$$K_8 \quad xq_1 1 \vdash$$

10.



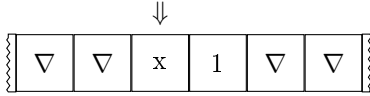
$$K_9 \quad xxq_2 \nabla \vdash$$

11.



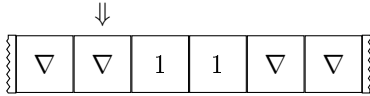
$$K_{10} \quad xq_3 x \vdash$$

12.



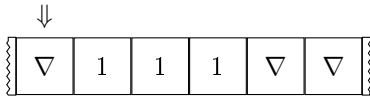
$$K_{11} \quad q_5 x1 \vdash$$

13.



$$K_{12} \quad q_5 \nabla 11 \vdash$$

14.



$$K_{13} \quad q_6 \nabla 111$$

1.3.2 f(6)

1. \Downarrow

∇	1	1	1	1	1	1	1	∇
----------	---	---	---	---	---	---	---	----------

 $K_0 \quad q_0 1111111 \vdash$
2. \Downarrow

∇	∇	1	1	1	1	1	1	∇
----------	----------	---	---	---	---	---	---	----------

 $K_1 \quad q_1 111111 \vdash$
3. \Downarrow

∇	∇	x	1	1	1	1	1	∇
----------	----------	---	---	---	---	---	---	----------

 $K_2 \quad xq_2 11111 \vdash$
4. \Downarrow

∇	∇	x	1	1	1	1	1	∇
----------	----------	---	---	---	---	---	---	----------

 $K_3 \quad x1q_2 1111 \vdash$
5. \Downarrow

∇	∇	x	1	1	1	1	1	∇
----------	----------	---	---	---	---	---	---	----------

 $K_4 \quad x11q_2 111 \vdash$
6. \Downarrow

∇	∇	x	1	1	1	1	1	∇
----------	----------	---	---	---	---	---	---	----------

 $K_5 \quad x111q_2 11 \vdash$
7. \Downarrow

∇	∇	x	1	1	1	1	1	∇
----------	----------	---	---	---	---	---	---	----------

 $K_6 \quad x1111q_2 1 \vdash$
8. \Downarrow

∇	∇	x	1	1	1	1	1	∇
----------	----------	---	---	---	---	---	---	----------

 $K_7 \quad x11111q_2 \nabla \vdash$
9. \Downarrow

∇	∇	x	1	1	1	1	1	∇
----------	----------	---	---	---	---	---	---	----------

 $K_8 \quad x1111q_3 1 \vdash$
10. \Downarrow

∇	∇	x	1	1	1	1	∇	∇
----------	----------	---	---	---	---	---	----------	----------

 $K_9 \quad x111q_4 1 \vdash$
11. \Downarrow

∇	∇	x	1	1	1	1	∇	∇
----------	----------	---	---	---	---	---	----------	----------

 $K_{10} \quad x11q_4 11 \vdash$
12. \Downarrow

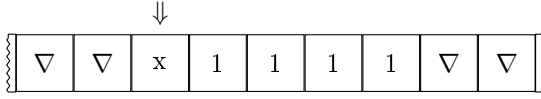
∇	∇	x	1	1	1	1	∇	∇
----------	----------	---	---	---	---	---	----------	----------

 $K_{11} \quad x1q_4 111 \vdash$
13. \Downarrow

∇	∇	x	1	1	1	1	∇	∇
----------	----------	---	---	---	---	---	----------	----------

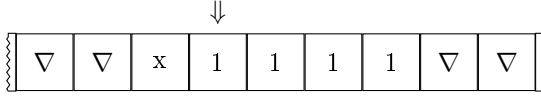
 $K_{12} \quad xq_4 1111 \vdash$

14.



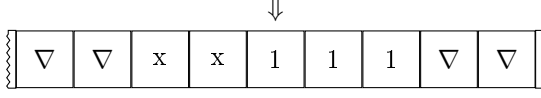
$$K_{13} \quad q_4 x 1 1 1 1 \vdash$$

15.



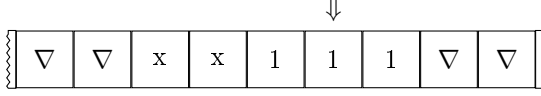
$$K_{14} \quad x q_1 1 1 1 1 \vdash$$

16.



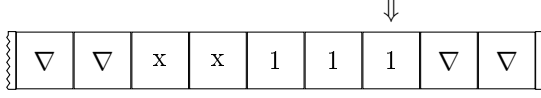
$$K_{15} \quad x x q_2 1 1 1 \vdash$$

17.



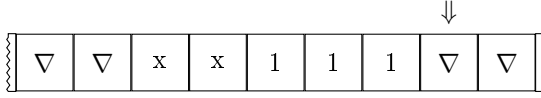
$$K_{16} \quad x x 1 q_2 1 1 \vdash$$

18.



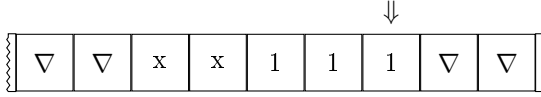
$$K_{17} \quad x x 1 1 q_2 1 \vdash$$

19.



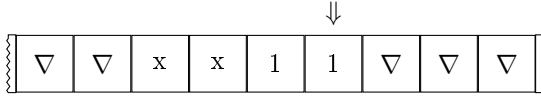
$$K_{18} \quad x x 1 1 1 q_2 \nabla \vdash$$

20.



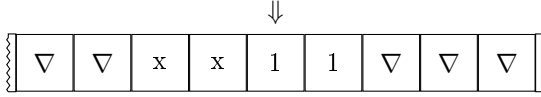
$$K_{19} \quad x x 1 1 q_3 1 \vdash$$

21.



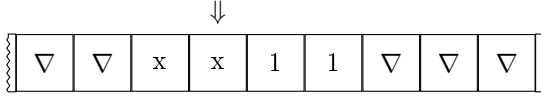
$$K_{20} \quad x x 1 q_4 1 \vdash$$

22.



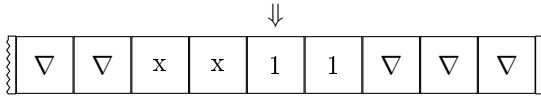
$$K_{21} \quad x x q_4 1 1 \vdash$$

23.



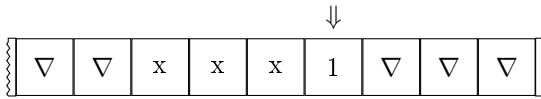
$$K_{22} \quad x q_4 x 1 1 \vdash$$

24.



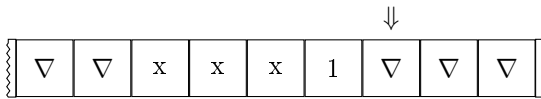
$$K_{23} \quad x x q_1 1 1 \vdash$$

25.



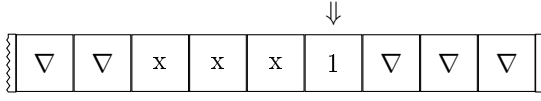
$$K_{24} \quad x x x q_2 1 \vdash$$

26.



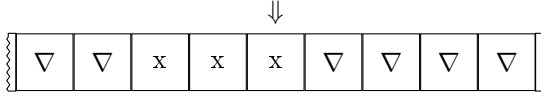
$$K_{25} \quad x x x 1 q_2 \nabla \vdash$$

27.



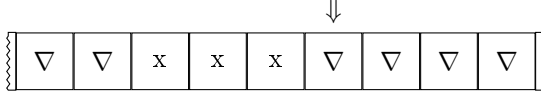
$K_{26} \quad xxxq_31 \vdash$

28.



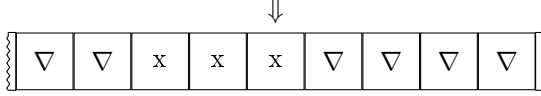
$K_{27} \quad xxq_4x \vdash$

29.



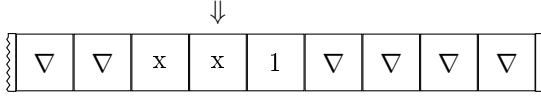
$K_{28} \quad xxxq_1\triangledown \vdash$

30.



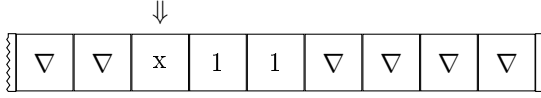
$K_{29} \quad xxq_5x \vdash$

31.



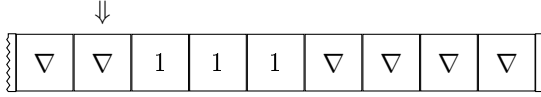
$K_{30} \quad xq_5x1 \vdash$

32.



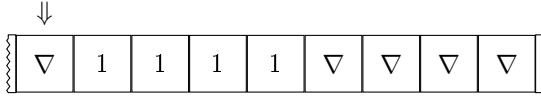
$K_{31} \quad q_5x11 \vdash$

33.



$K_{32} \quad q_5\triangledown111 \vdash$

34.



$K_{33} \quad q_6\triangledown1111$

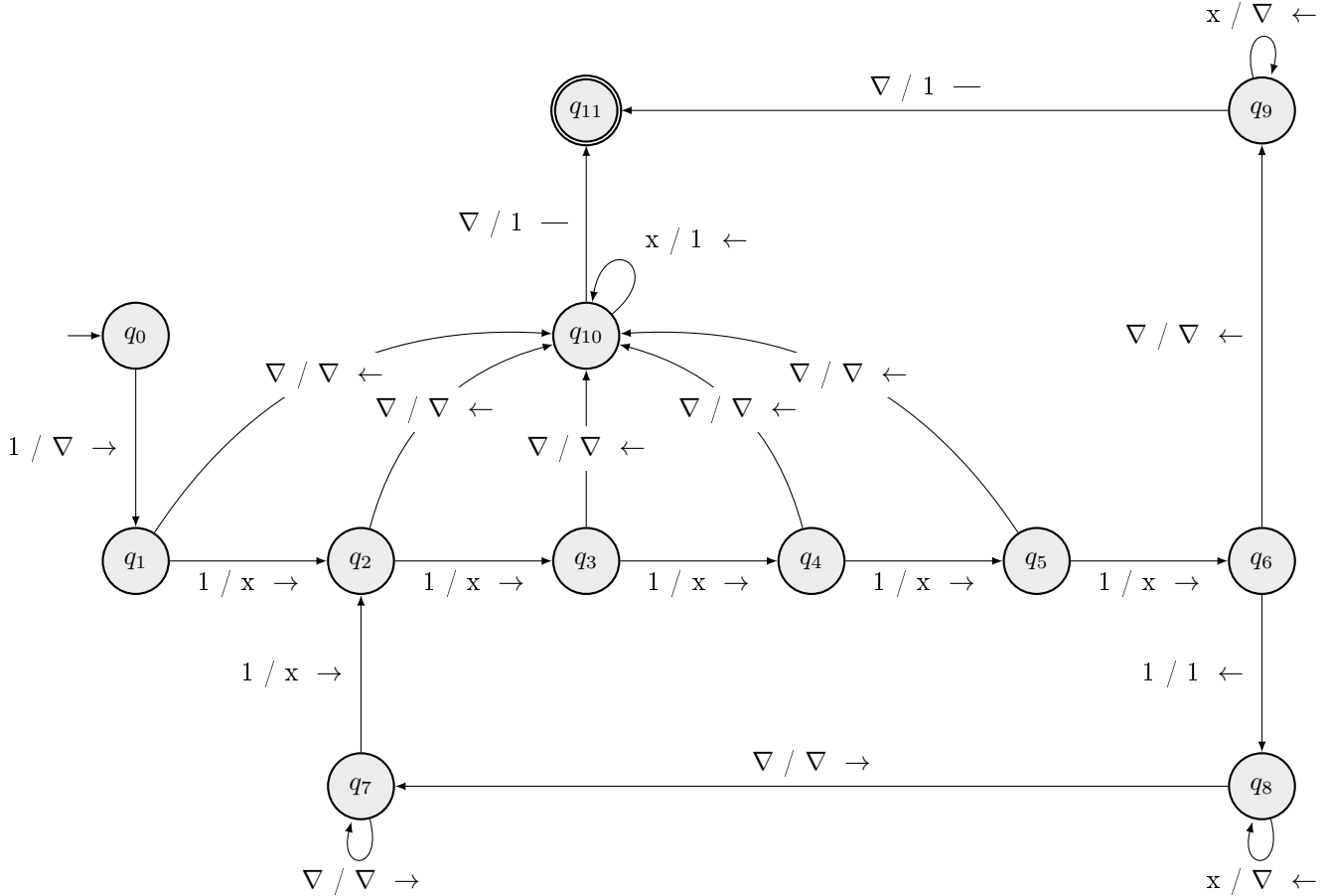
1.4 Zadanie 1.4

Zaprojektuj maszynę Turinga, które oblicza funkcję f dla liczby naturalnej n w reprezentacji unarnej, gdzie

$$(7) \quad f(n) = n \bmod 5$$

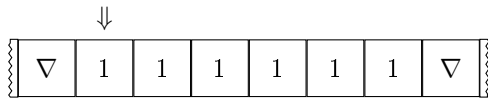
Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(8) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_8, q_9, q_{10}, q_{11}\}, \{1\}, \{1, x, \nabla\}, \delta, q_0, \nabla, \{q_{11}\})$$



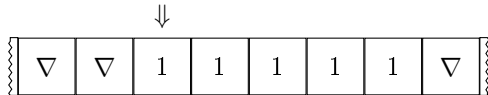
1.4.1 $f(5)$

1.



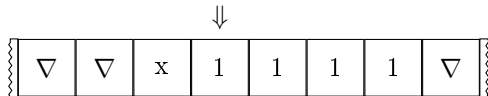
$K_0 \quad q_0 111111 \vdash$

2.



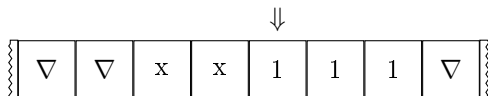
$K_1 \quad q_1 11111 \vdash$

3.



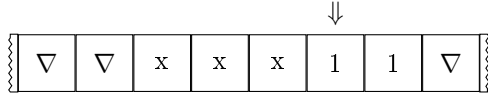
$K_2 \quad xq_2 1111 \vdash$

4.



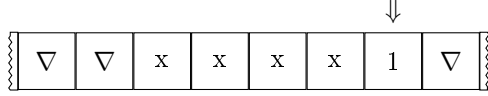
$K_3 \quad xxq_3 111 \vdash$

5.



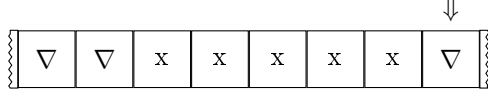
$K_4 \quad \text{xxx}q_411 \vdash$

6.



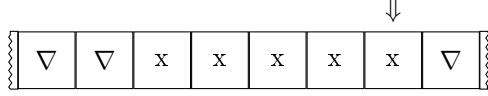
$K_5 \quad \text{xxxx}q_51 \vdash$

7.



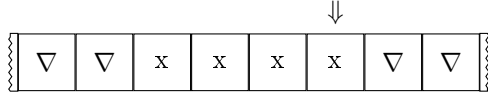
$K_6 \quad \text{xxxxx}q_6\triangledown \vdash$

8.



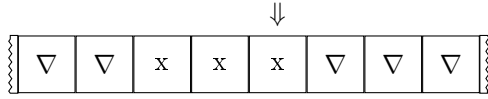
$K_7 \quad \text{xxxx}q_9x \vdash$

9.



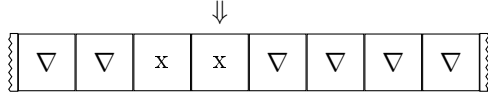
$K_8 \quad \text{xxx}q_9x \vdash$

10.



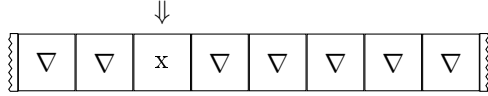
$K_9 \quad \text{xx}q_9x \vdash$

11.



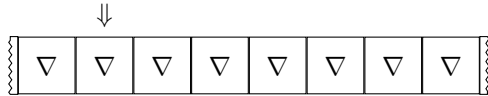
$K_{10} \quad \text{x}q_9x \vdash$

12.



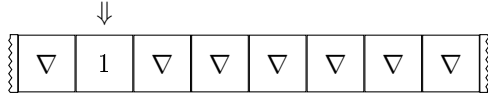
$K_{11} \quad q_9x \vdash$

13.



$K_{12} \quad q_9\triangledown \vdash$

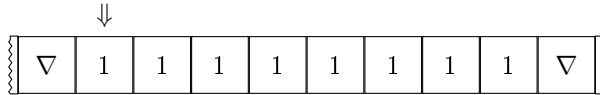
14.



$K_{13} \quad q_{11}1$

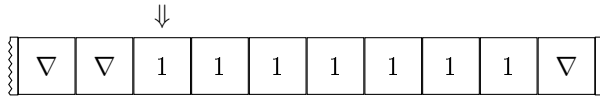
1.4.2 f(7)

1.



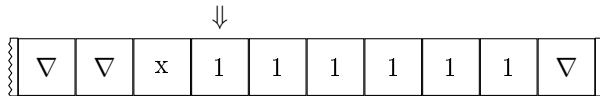
$K_0 \quad q_011111111 \vdash$

2.



$K_1 \quad q_11111111 \vdash$

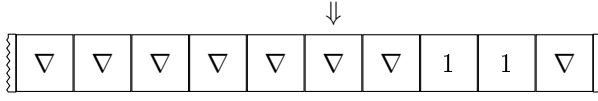
3.



$K_2 \quad \text{x}q_2111111 \vdash$

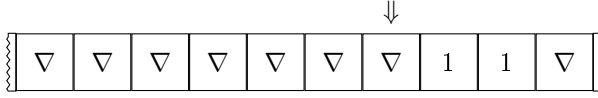
4.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_3 \quad xxq_3 11111 \vdash$
5.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_4 \quad xxxq_4 1111 \vdash$
6.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_5 \quad xxxxq_5 111 \vdash$
7.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_6 \quad xxxxxq_6 11 \vdash$
8.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_7 \quad xxxxq_8 x 11 \vdash$
9.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_8 \quad xxxq_8 x \nabla 11 \vdash$
10.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_9 \quad xxq_8 x \nabla \nabla 11 \vdash$
11.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{10} \quad xq_8 x \nabla \nabla \nabla 11 \vdash$
12.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> x </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{11} \quad q_8 x \nabla \nabla \nabla \nabla 11 \vdash$
13.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{12} \quad q_8 \nabla \nabla \nabla \nabla \nabla 11 \vdash$
14.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{13} \quad q_7 \nabla \nabla \nabla \nabla \nabla 11 \vdash$
15.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{14} \quad q_7 \nabla \nabla \nabla \nabla 11 \vdash$
16.	\Downarrow <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> ∇ </div> </div>	$K_{15} \quad q_7 \nabla \nabla \nabla 11 \vdash$

17.



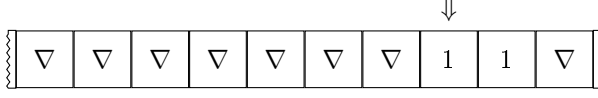
$$K_{16} \quad q_7 \nabla \nabla 11 \vdash$$

18.



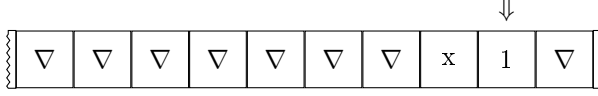
$$K_{17} \quad q_7 \nabla 11 \vdash$$

19.



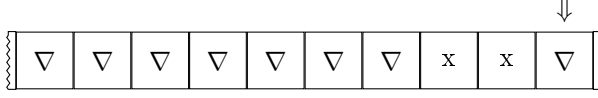
$$K_{18} \quad q_7 11 \vdash$$

20.



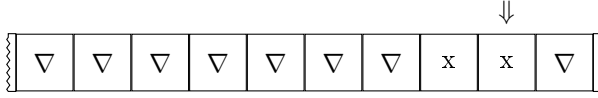
$$K_{19} \quad x q_2 1 \vdash$$

21.



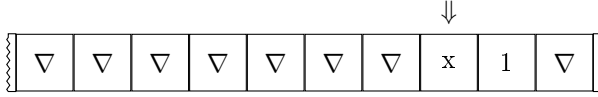
$$K_{20} \quad x x q_3 \nabla \vdash$$

22.



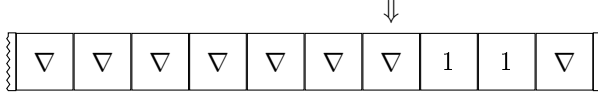
$$K_{21} \quad x q_{10} x \vdash$$

23.



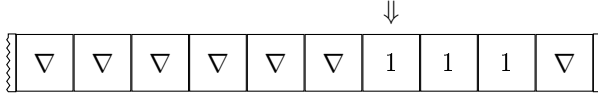
$$K_{22} \quad q_{10} x 1 \vdash$$

24.



$$K_{23} \quad q_{10} \nabla 11 \vdash$$

25.



$$K_{24} \quad q_{11} 111$$

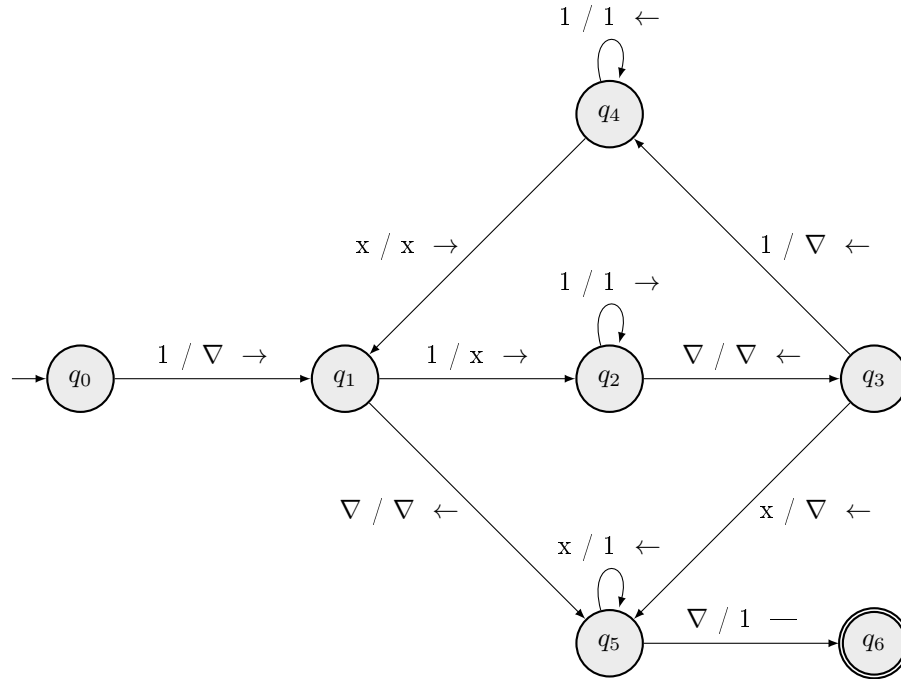
1.5 Zadanie 1.5

Zaprojektuj maszynę Turinga, które oblicza funkcję f dla liczby naturalnej n w reprezentacji unarnej, gdzie

$$(9) \quad f(n) = \left\lfloor \frac{n}{2} \right\rfloor$$

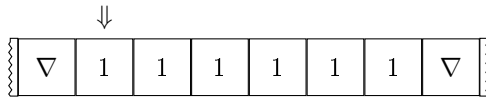
Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(10) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6\}, \{1\}, \{1, x, \nabla\}, \delta, q_0, \nabla, \{q_6\})$$



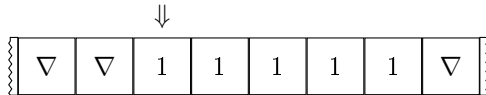
1.5.1 $f(5)$

1.



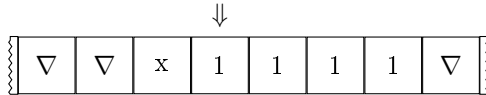
$K_0 \quad q_0 111111 \vdash$

2.



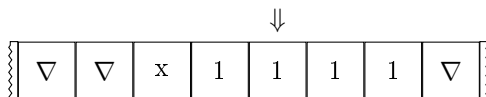
$K_1 \quad q_1 11111 \vdash$

3.



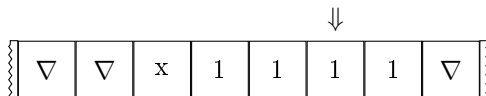
$K_2 \quad x q_2 1111 \vdash$

4.



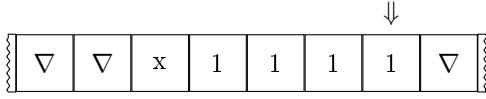
$K_3 \quad x 1 q_2 111 \vdash$

5.



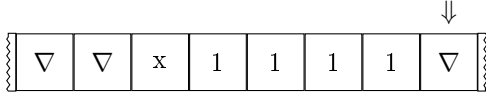
$K_4 \quad x 11 q_2 11 \vdash$

6.



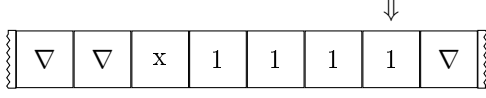
$$K_5 \quad x111q_21 \vdash$$

7.



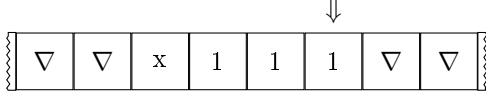
$$K_6 \quad x1111q_2\nabla \vdash$$

8.



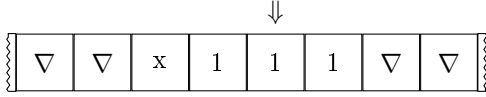
$$K_7 \quad x111q_31 \vdash$$

9.



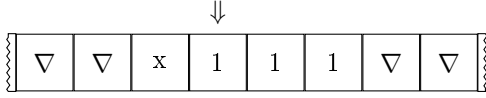
$$K_8 \quad x11q_41 \vdash$$

10.



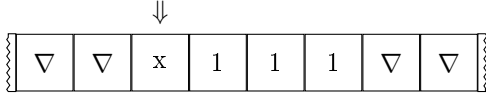
$$K_9 \quad x1q_411 \vdash$$

11.



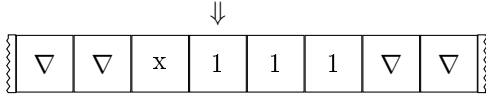
$$K_{10} \quad xq_4111 \vdash$$

12.



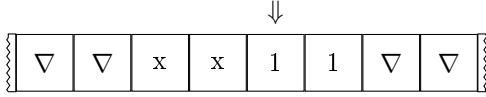
$$K_{11} \quad q_4x111 \vdash$$

13.



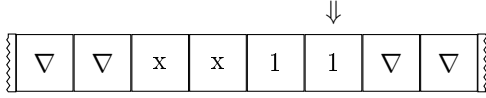
$$K_{12} \quad xq_1111 \vdash$$

14.



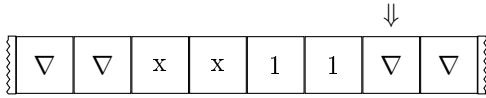
$$K_{13} \quad xxq_211 \vdash$$

15.



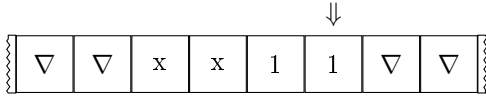
$$K_{14} \quad xx1q_21 \vdash$$

16.



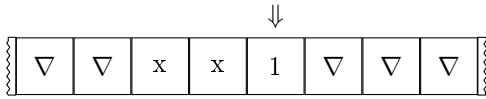
$$K_{15} \quad xx11q_2\nabla \vdash$$

17.



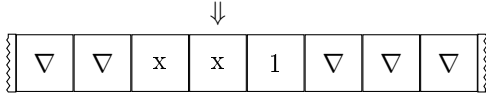
$$K_{16} \quad xx1q_31 \vdash$$

18.



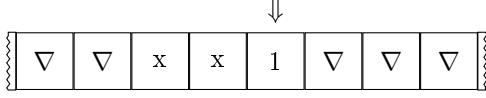
$$K_{17} \quad xxq_41 \vdash$$

19.



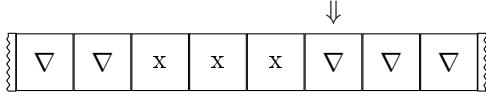
$$K_{18} \quad xq_4x1 \vdash$$

20.



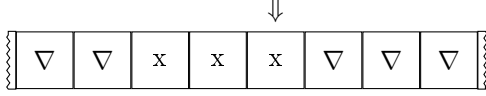
$$K_{19} \quad xxq_11 \vdash$$

21.



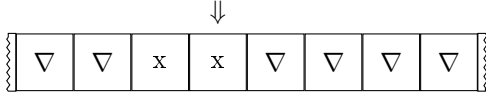
$$K_{20} \quad xxxq_2\nabla \vdash$$

22.



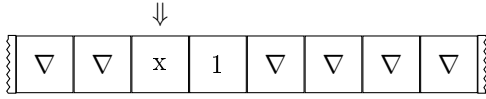
$$K_{21} \quad xxq_3x \vdash$$

23.



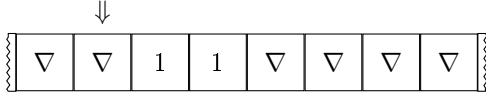
$$K_{22} \quad xq_5x \vdash$$

24.



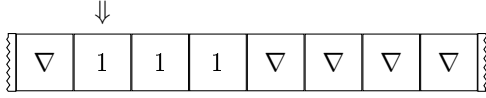
$$K_{23} \quad q_5x1 \vdash$$

25.



$$K_{24} \quad q_5\nabla 11 \vdash$$

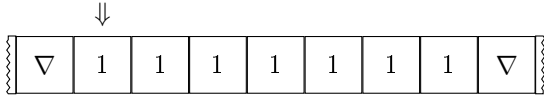
26.



$$K_{25} \quad q_6111$$

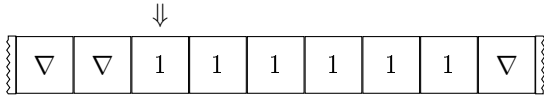
1.5.2 f(6)

1.



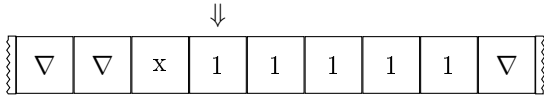
$$K_0 \quad q_01111111 \vdash$$

2.



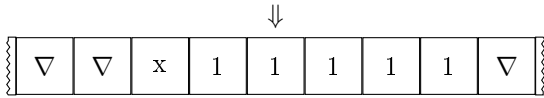
$$K_1 \quad q_1111111 \vdash$$

3.



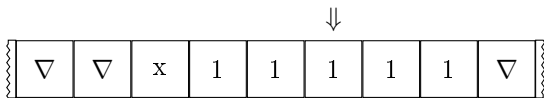
$$K_2 \quad xq_211111 \vdash$$

4.



$$K_3 \quad x1q_21111 \vdash$$

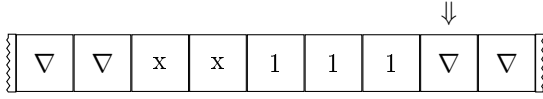
5.



$$K_4 \quad x11q_2111 \vdash$$

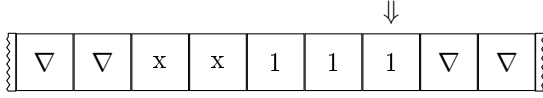
6. \Downarrow
- | | | | | | | | | |
|----------|----------|---|---|---|---|---|---|----------|
| ∇ | ∇ | x | 1 | 1 | 1 | 1 | 1 | ∇ |
|----------|----------|---|---|---|---|---|---|----------|
- $K_5 \quad x111q_211 \vdash$
7. \Downarrow
- | | | | | | | | | |
|----------|----------|---|---|---|---|---|---|----------|
| ∇ | ∇ | x | 1 | 1 | 1 | 1 | 1 | ∇ |
|----------|----------|---|---|---|---|---|---|----------|
- $K_6 \quad x1111q_21 \vdash$
8. \Downarrow
- | | | | | | | | | |
|----------|----------|---|---|---|---|---|---|----------|
| ∇ | ∇ | x | 1 | 1 | 1 | 1 | 1 | ∇ |
|----------|----------|---|---|---|---|---|---|----------|
- $K_7 \quad x11111q_2\nabla \vdash$
9. \Downarrow
- | | | | | | | | | |
|----------|----------|---|---|---|---|---|---|----------|
| ∇ | ∇ | x | 1 | 1 | 1 | 1 | 1 | ∇ |
|----------|----------|---|---|---|---|---|---|----------|
- $K_8 \quad x1111q_31 \vdash$
10. \Downarrow
- | | | | | | | | | |
|----------|----------|---|---|---|---|---|----------|----------|
| ∇ | ∇ | x | 1 | 1 | 1 | 1 | ∇ | ∇ |
|----------|----------|---|---|---|---|---|----------|----------|
- $K_9 \quad x111q_41 \vdash$
11. \Downarrow
- | | | | | | | | | |
|----------|----------|---|---|---|---|---|----------|----------|
| ∇ | ∇ | x | 1 | 1 | 1 | 1 | ∇ | ∇ |
|----------|----------|---|---|---|---|---|----------|----------|
- $K_{10} \quad x11q_411 \vdash$
12. \Downarrow
- | | | | | | | | | |
|----------|----------|---|---|---|---|---|----------|----------|
| ∇ | ∇ | x | 1 | 1 | 1 | 1 | ∇ | ∇ |
|----------|----------|---|---|---|---|---|----------|----------|
- $K_{11} \quad x1q_4111 \vdash$
13. \Downarrow
- | | | | | | | | | |
|----------|----------|---|---|---|---|---|----------|----------|
| ∇ | ∇ | x | 1 | 1 | 1 | 1 | ∇ | ∇ |
|----------|----------|---|---|---|---|---|----------|----------|
- $K_{12} \quad xq_41111 \vdash$
14. \Downarrow
- | | | | | | | | | |
|----------|----------|---|---|---|---|---|----------|----------|
| ∇ | ∇ | x | 1 | 1 | 1 | 1 | ∇ | ∇ |
|----------|----------|---|---|---|---|---|----------|----------|
- $K_{13} \quad q_4x1111 \vdash$
15. \Downarrow
- | | | | | | | | | |
|----------|----------|---|---|---|---|---|----------|----------|
| ∇ | ∇ | x | 1 | 1 | 1 | 1 | ∇ | ∇ |
|----------|----------|---|---|---|---|---|----------|----------|
- $K_{14} \quad xq_11111 \vdash$
16. \Downarrow
- | | | | | | | | | |
|----------|----------|---|---|---|---|---|----------|----------|
| ∇ | ∇ | x | x | 1 | 1 | 1 | ∇ | ∇ |
|----------|----------|---|---|---|---|---|----------|----------|
- $K_{15} \quad xxq_2111 \vdash$
17. \Downarrow
- | | | | | | | | | |
|----------|----------|---|---|---|---|---|----------|----------|
| ∇ | ∇ | x | x | 1 | 1 | 1 | ∇ | ∇ |
|----------|----------|---|---|---|---|---|----------|----------|
- $K_{16} \quad xx1q_211 \vdash$
18. \Downarrow
- | | | | | | | | | |
|----------|----------|---|---|---|---|---|----------|----------|
| ∇ | ∇ | x | x | 1 | 1 | 1 | ∇ | ∇ |
|----------|----------|---|---|---|---|---|----------|----------|
- $K_{17} \quad xx11q_21 \vdash$

19.



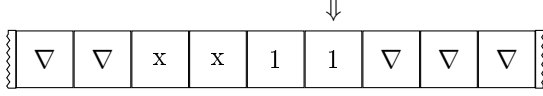
$$K_{18} \quad \text{xx111}q_2\nabla \vdash$$

20.



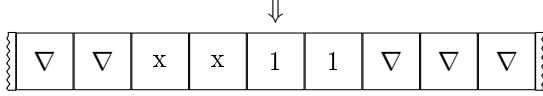
$$K_{19} \quad \text{xx11}q_31 \vdash$$

21.



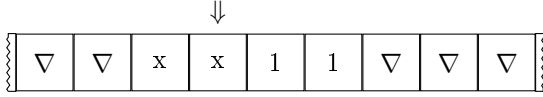
$$K_{20} \quad \text{xx1}q_41 \vdash$$

22.



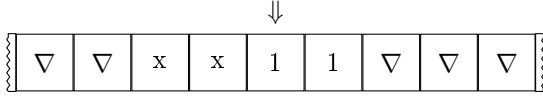
$$K_{21} \quad \text{xx}q_411 \vdash$$

23.



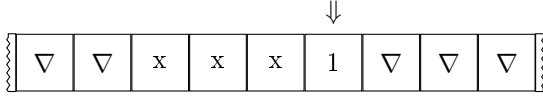
$$K_{22} \quad \text{x}q_4\text{x}11 \vdash$$

24.



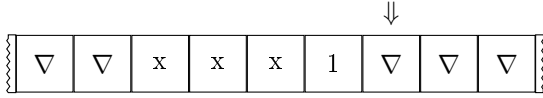
$$K_{23} \quad \text{xx}q_111 \vdash$$

25.



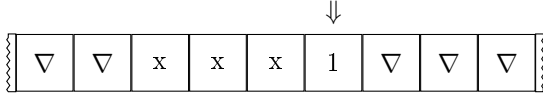
$$K_{24} \quad \text{xxx}q_21 \vdash$$

26.



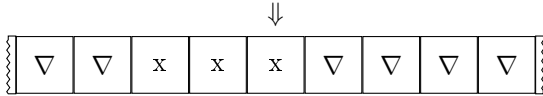
$$K_{25} \quad \text{xxx1}q_2\nabla \vdash$$

27.



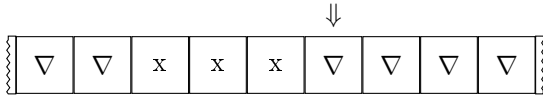
$$K_{26} \quad \text{xxx}q_31 \vdash$$

28.



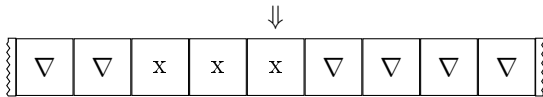
$$K_{27} \quad \text{xx}q_4\text{x} \vdash$$

29.



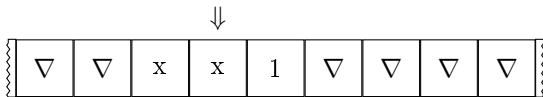
$$K_{28} \quad \text{xxx}q_1\nabla \vdash$$

30.



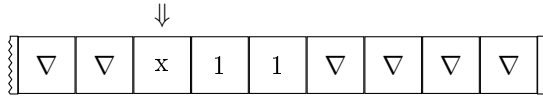
$$K_{29} \quad \text{xx}q_5\text{x} \vdash$$

31.



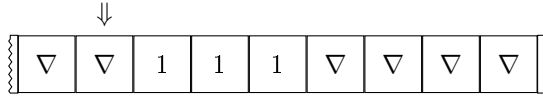
$$K_{30} \quad \text{x}q_5\text{x}1 \vdash$$

32.



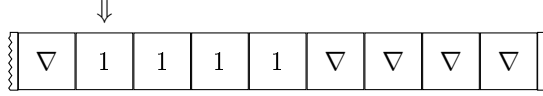
$K_{31} \quad q_5 x 11 \vdash$

33.



$K_{32} \quad q_5 \nabla 111 \vdash$

34.



$K_{33} \quad q_6 1111$

1.6 Zadanie 1.6

Zadanie 1.6 i zadanie 1.3 polegają na tym samym, różni się tylko zapis

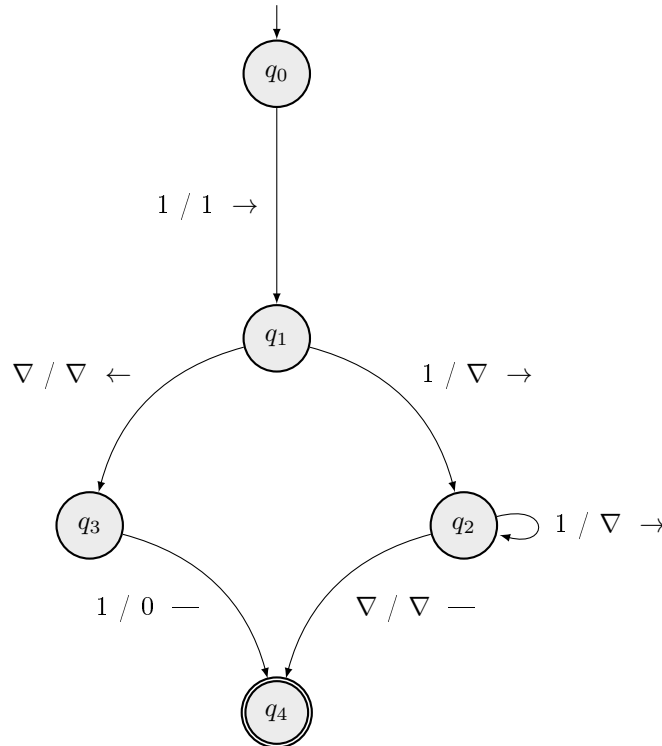
1.7 Zadanie 1.7

Zaprojektuj maszynę Turinga, które oblicza funkcję signum (znaku)

$$(11) \quad \text{sgn}(n) = \begin{cases} 1, & \text{jeżeli } n \geq 0, \\ 0, & \text{jeżeli } n < 0 \end{cases}$$

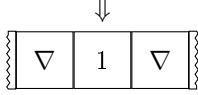
Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(12) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4\}, \{1\}, \{1, 0, \nabla\}, \delta, q_0, \nabla, \{q_4\})$$



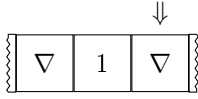
1.7.1 $\text{sgn}(0)$

1.



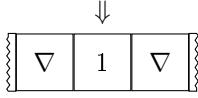
$$K_0 \quad q_0 1 \quad \vdash$$

2.



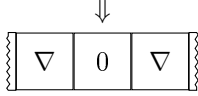
$$K_1 \quad 1q_1 \nabla \quad \vdash$$

3.



$$K_2 \quad q_3 1 \quad \vdash$$

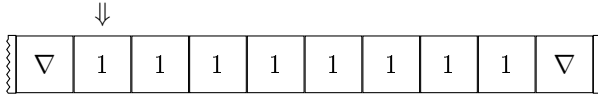
4.



$$K_3 \quad q_4 0$$

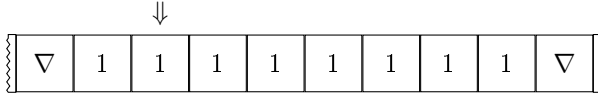
1.7.2 $\text{sgn}(7)$

1.



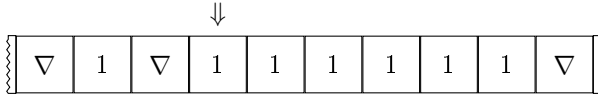
$$K_0 \quad q_0 11111111 \quad \vdash$$

2.



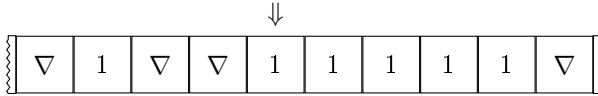
$$K_1 \quad 1q_1 11111111 \quad \vdash$$

3.



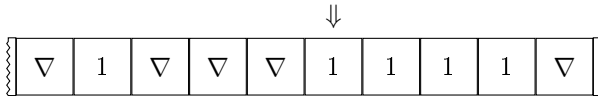
$$K_2 \quad 1\nabla q_2 11111111 \quad \vdash$$

4.



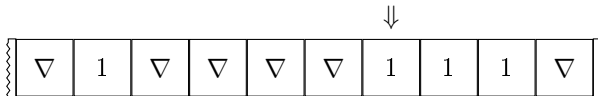
$$K_3 \quad 1\nabla\nabla q_2 111111 \quad \vdash$$

5.



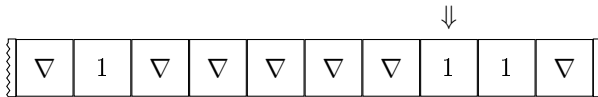
$$K_4 \quad 1\nabla\nabla\nabla q_2 11111 \quad \vdash$$

6.



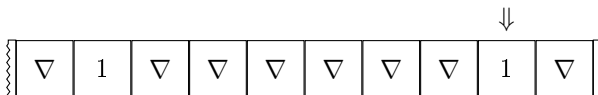
$$K_5 \quad 1\nabla\nabla\nabla\nabla q_2 1111 \quad \vdash$$

7.



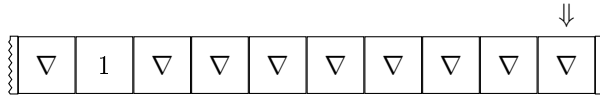
$$K_6 \quad 1\nabla\nabla\nabla\nabla\nabla q_2 11 \quad \vdash$$

8.



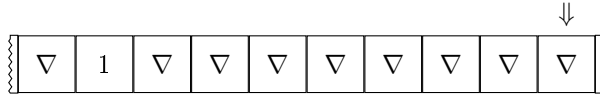
$$K_7 \quad 1\nabla\nabla\nabla\nabla\nabla\nabla q_2 1 \quad \vdash$$

9.



$$K_8 \quad 1 \nabla \nabla \nabla \nabla \nabla \nabla \nabla \nabla q_2 \nabla \quad \vdash$$

10.



$$K_9 \quad 1 \nabla \nabla \nabla \nabla \nabla \nabla \nabla q_4 \nabla$$

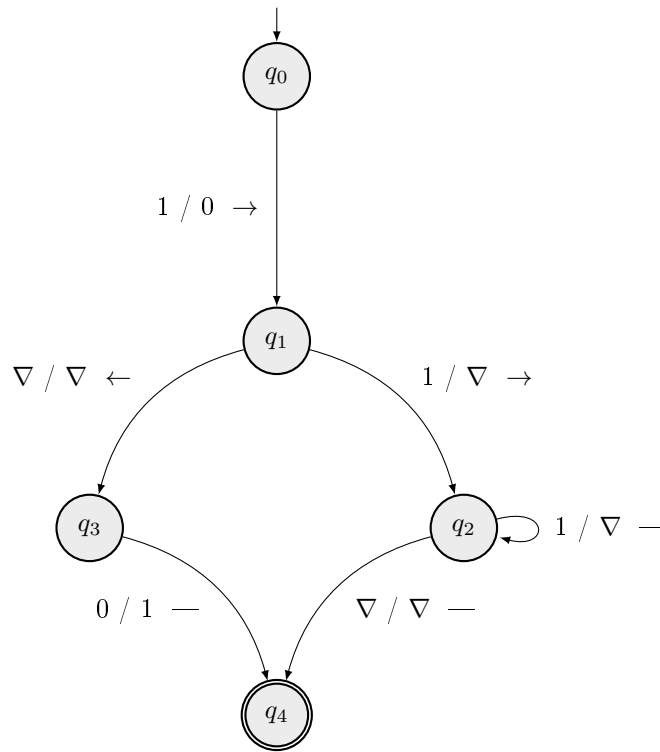
1.8 Zadanie 1.8

Zaprojektuj maszynę Turinga, które oblicza funkcję dopełnienie signum

$$(13) \quad \overline{sgn}(n) = \begin{cases} 0, & \text{jeżeli } n \geq 0, \\ 1, & \text{jeżeli } n = 0 \end{cases}$$

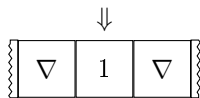
Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(14) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4\}, \{1\}, \{1, 0, \nabla\}, \delta, q_0, \nabla, \{q_4\})$$



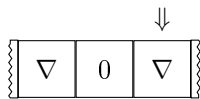
1.8.1 $\overline{sgn}(0)$

1.



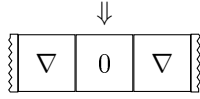
$$K_0 \quad q_0 1 \quad \vdash$$

2.



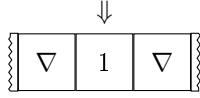
$$K_1 \quad 0 q_1 \nabla \quad \vdash$$

3.



$K_2 \quad q_3 0 \vdash$

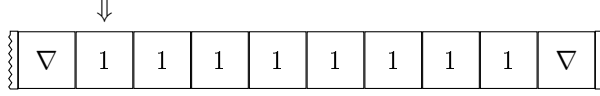
4.



$K_3 \quad q_4 1$

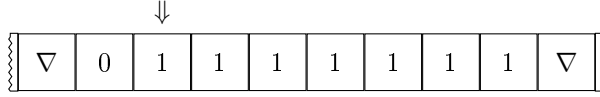
1.8.2 $\overline{sgn}(7)$

1.



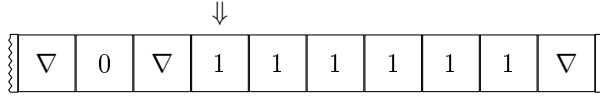
$K_0 \quad q_0 11111111 \vdash$

2.



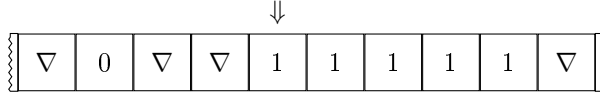
$K_1 \quad 0q_1 11111111 \vdash$

3.



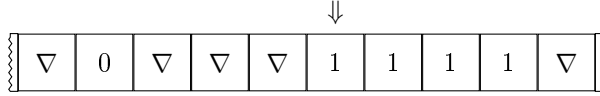
$K_2 \quad 0\nabla q_2 11111111 \vdash$

4.



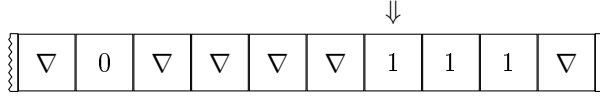
$K_3 \quad 0\nabla\nabla q_2 111111 \vdash$

5.



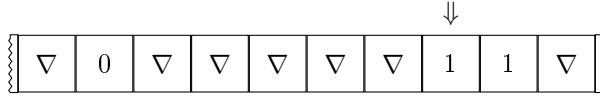
$K_4 \quad 0\nabla\nabla\nabla q_2 11111 \vdash$

6.



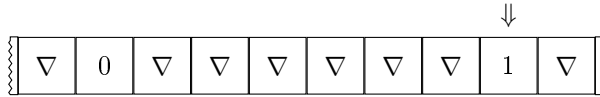
$K_5 \quad 0\nabla\nabla\nabla\nabla q_2 1111 \vdash$

7.



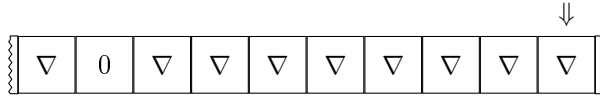
$K_6 \quad 0\nabla\nabla\nabla\nabla\nabla q_2 11 \vdash$

8.



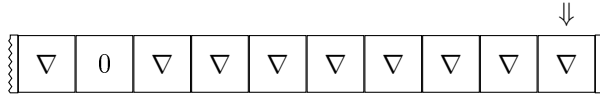
$K_7 \quad 0\nabla\nabla\nabla\nabla\nabla\nabla q_2 1 \vdash$

9.



$K_8 \quad 0\nabla\nabla\nabla\nabla\nabla\nabla\nabla q_2 \nabla \vdash$

10.



$K_9 \quad 0\nabla\nabla\nabla\nabla\nabla\nabla\nabla\nabla q_4 \nabla$

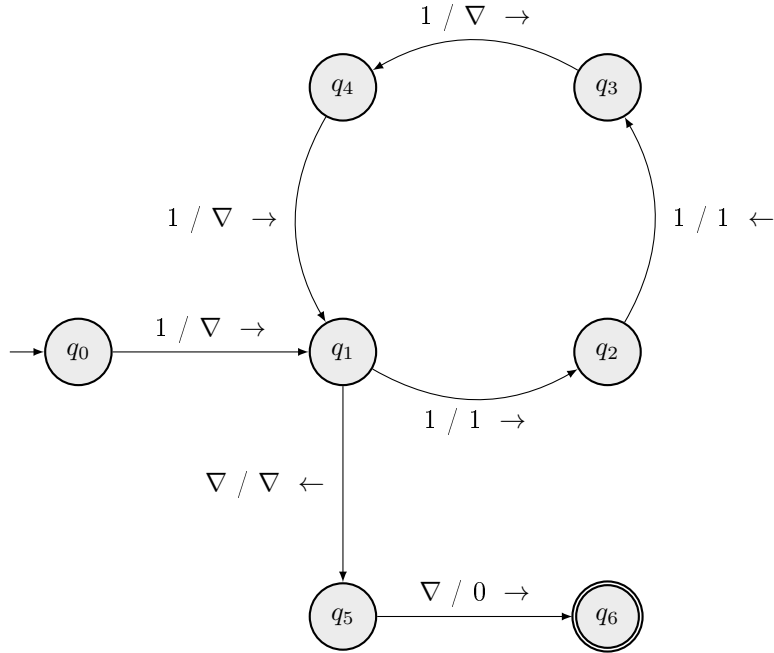
1.9 Zadanie 1.9

Zaprojektuj maszynę Turinga, które oblicza funkcję

$$(15) \quad f(n) = \begin{cases} 0, & \text{jeżeli } n \text{ jest parzysta,} \\ 1, & \text{jeżeli } n \text{ jest nieparzysta} \end{cases}$$

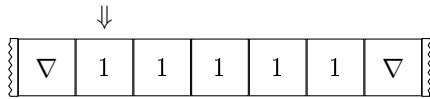
Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(16) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6\}, \{1\}, \{1, 0, \nabla\}, \delta, q_0, \nabla, \{q_6\})$$



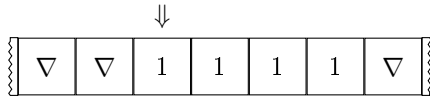
1.9.1 f(4)

1.



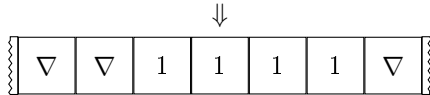
$K_0 \quad q_0 11111 \vdash$

2.



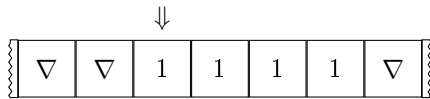
$K_1 \quad q_1 1111 \vdash$

3.



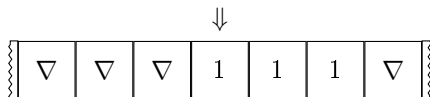
$K_2 \quad 1q_2 111 \vdash$

4.



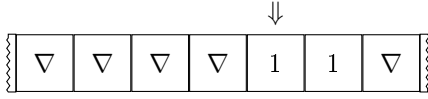
$K_3 \quad q_3 1111 \vdash$

5.

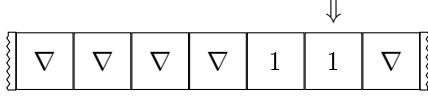


$K_4 \quad q_4 111 \vdash$

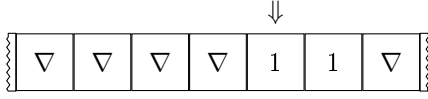
6.

 $K_5 \quad q_1 11 \vdash$

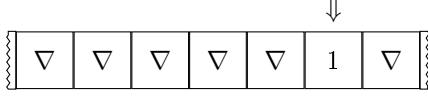
7.

 $K_6 \quad 1q_2 1 \vdash$

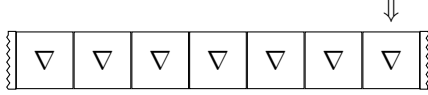
8.

 $K_7 \quad q_3 11 \vdash$

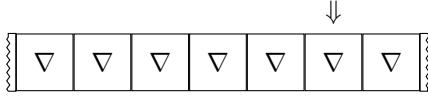
9.

 $K_8 \quad q_4 1 \vdash$

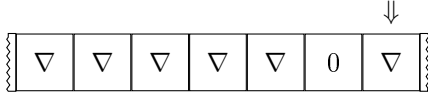
10.

 $K_9 \quad q_1 \nabla \vdash$

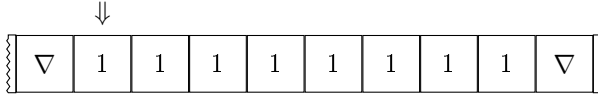
11.

 $K_{10} \quad q_5 \nabla \vdash$

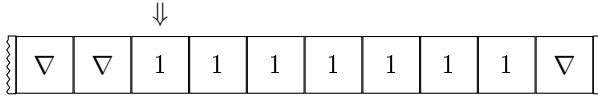
12.

 $K_{11} \quad 0q_6 \nabla$ **1.9.2 f(7)**

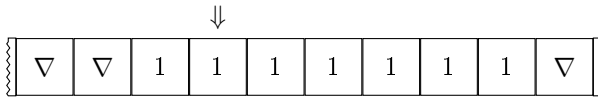
1.

 $K_0 \quad q_0 11111111 \vdash$

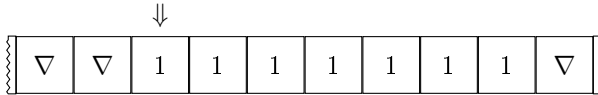
2.

 $K_1 \quad q_1 11111111 \vdash$

3.

 $K_2 \quad 1q_2 11111111 \vdash$

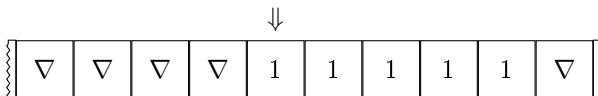
4.

 $K_3 \quad q_3 11111111 \vdash$

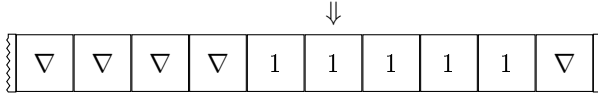
5.

 $K_4 \quad q_4 11111111 \vdash$

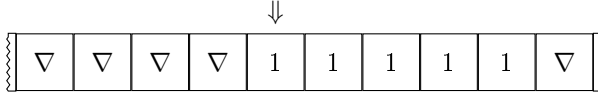
6.

 $K_5 \quad q_1 111111 \vdash$

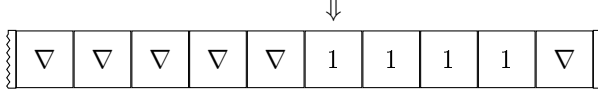
7.

 $K_6 \quad 1q_21111 \vdash$

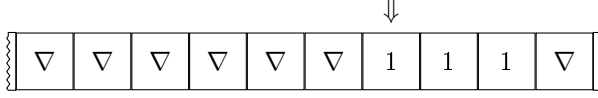
8.

 $K_7 \quad q_311111 \vdash$

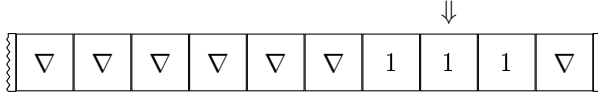
9.

 $K_8 \quad q_41111 \vdash$

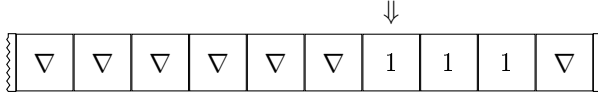
10.

 $K_9 \quad q_1111 \vdash$

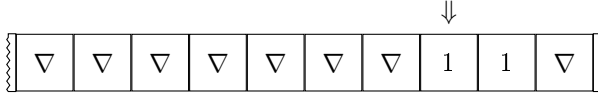
11.

 $K_{10} \quad 1q_211 \vdash$

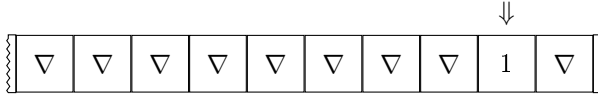
12.

 $K_{11} \quad q_3111 \vdash$

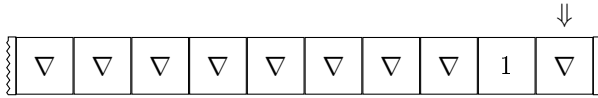
13.

 $K_{12} \quad q_411 \vdash$

14.

 $K_{13} \quad q_11 \vdash$

15.

 $K_{14} \quad 1q_2\nabla$

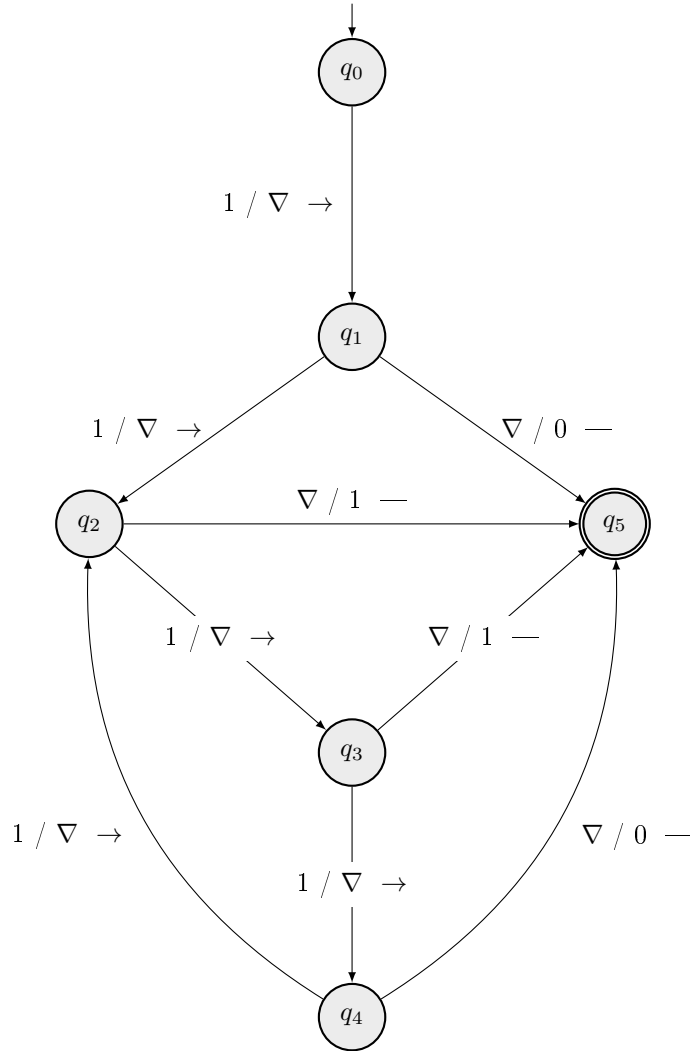
1.10 Zadanie 1.10

Zaprojektuj maszynę Turinga, które oblicza funkcję

$$(17) \quad f(n) = \begin{cases} 0, & \text{jeżeli } n \text{ jest podzielna przez } 3, \\ 1, & \text{jeżeli } n \text{ nie jest podzielna przez } 3 \end{cases}$$

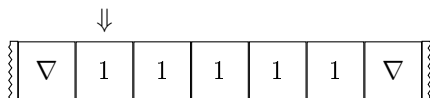
Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(18) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4, q_5\}, \{1\}, \{1, 0, \nabla\}, \delta, q_0, \nabla, \{q_5\})$$



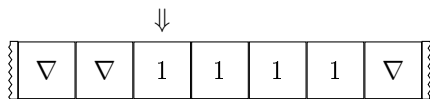
1.10.1 f(4)

1.



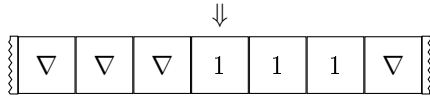
$K_0 \quad q_0 11111 \vdash$

2.



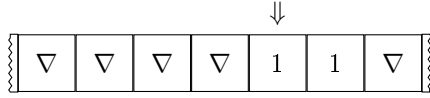
$K_1 \quad q_1 1111 \vdash$

3.



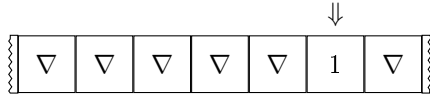
$K_2 \quad q_2 111 \vdash$

4.



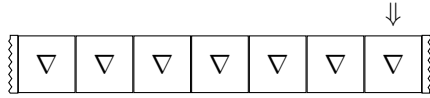
$K_3 \quad q_3 11 \vdash$

5.



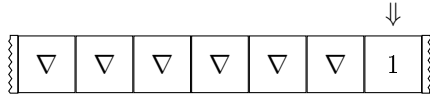
$K_4 \quad q_4 1 \vdash$

6.



$K_5 \quad q_2 \nabla \vdash$

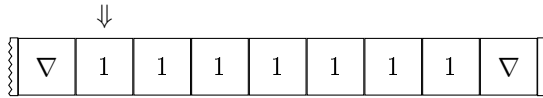
7.



$K_6 \quad q_5 1$

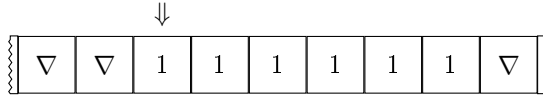
1.10.2 f(6)

1.



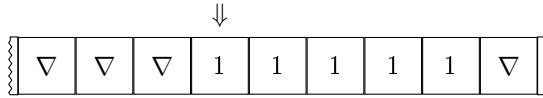
$K_0 \quad q_0 1111111 \vdash$

2.



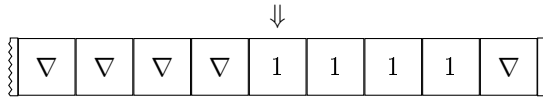
$K_1 \quad q_1 111111 \vdash$

3.



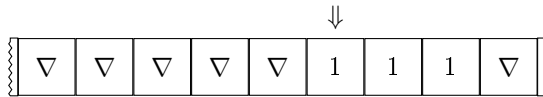
$K_2 \quad q_2 11111 \vdash$

4.



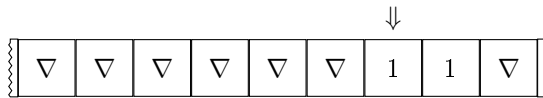
$K_3 \quad q_3 1111 \vdash$

5.



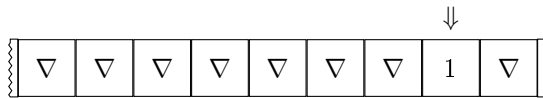
$K_4 \quad q_4 111 \vdash$

6.



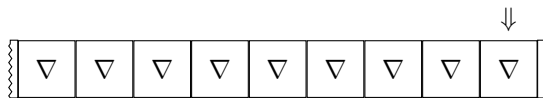
$K_5 \quad q_2 11 \vdash$

7.



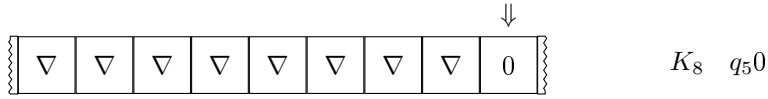
$K_6 \quad q_3 1 \vdash$

8.



$K_7 \quad q_4 \nabla \vdash$

9.



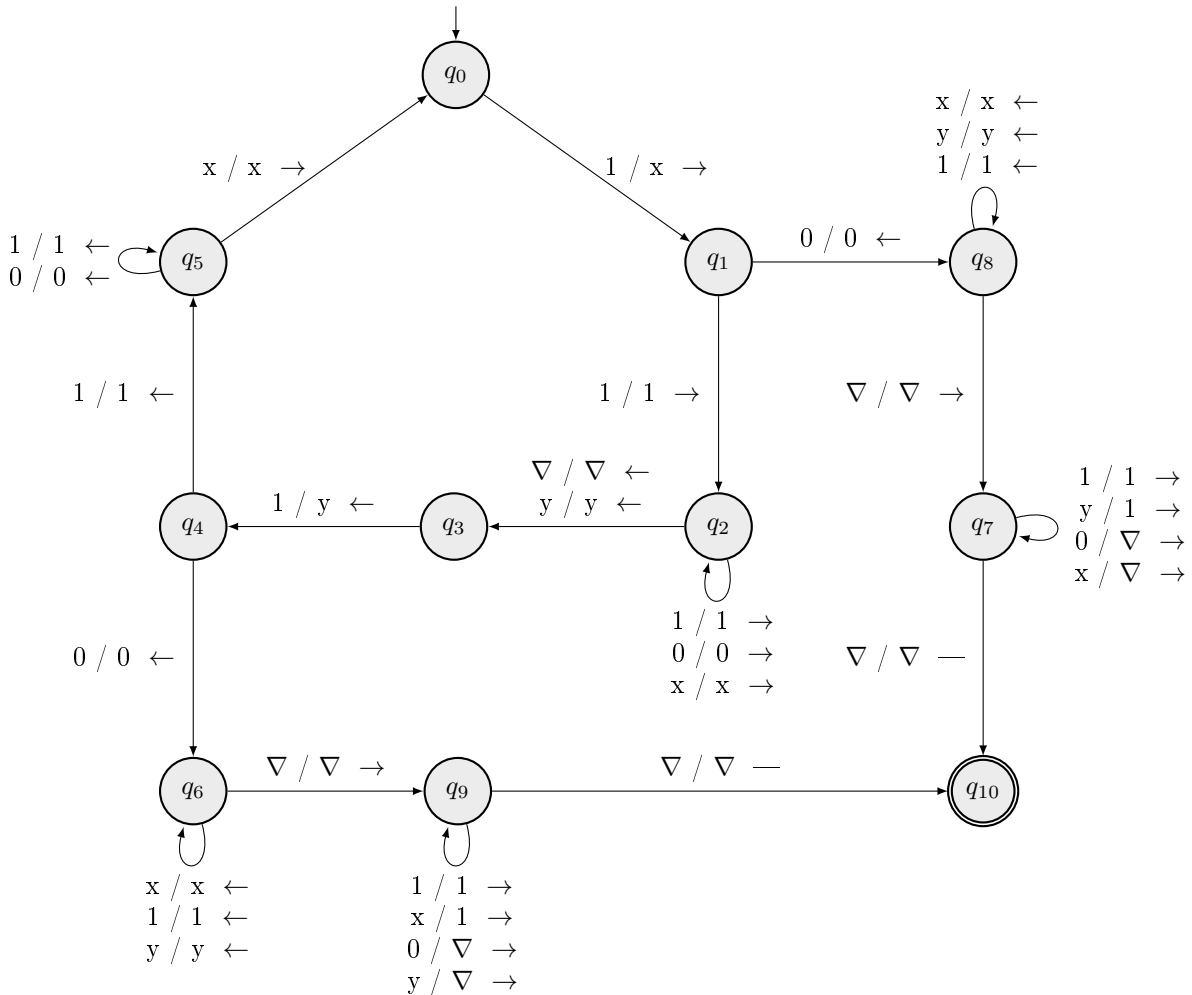
1.11 Zadanie 1.11

Zaprojektuj maszynę Turinga, które oblicza funkcję maksimum dla liczb naturalnych m i n w reprezentacji unarnej, czyli

$$(19) \quad f(m, n) = \max(m, n).$$

Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(20) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_8, q_9, q_{10}\}, \{1, 0\}, \{1, 0, x, y, \nabla\}, \delta, q_0, \nabla, \{q_{10}\})$$

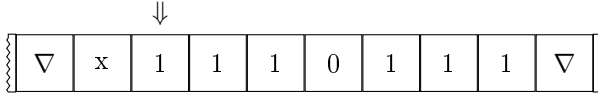


1.11.1 max(3, 2)

1.

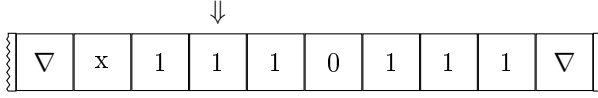


2.



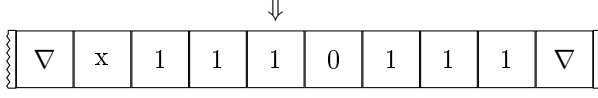
$$K_1 \quad xq_11110111 \vdash$$

3.



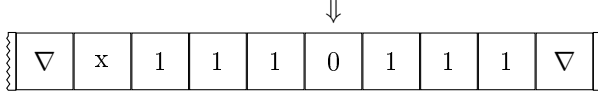
$$K_2 \quad x1q_2110111 \vdash$$

4.



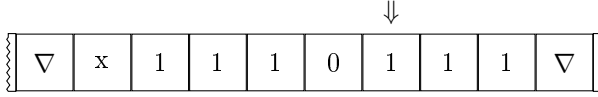
$$K_3 \quad x11q_210111 \vdash$$

5.



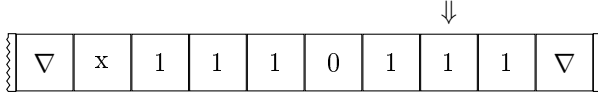
$$K_4 \quad x111q_20111 \vdash$$

6.



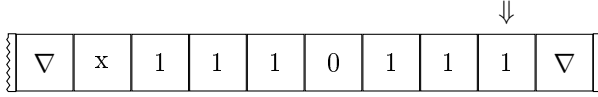
$$K_5 \quad x1110q_2111 \vdash$$

7.



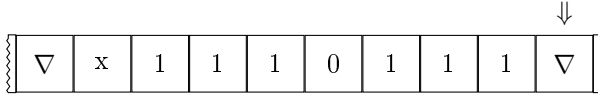
$$K_6 \quad x11101q_211 \vdash$$

8.



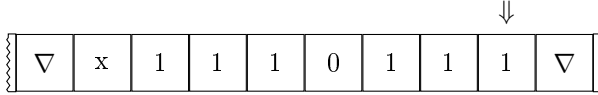
$$K_7 \quad x111011q_21 \vdash$$

9.



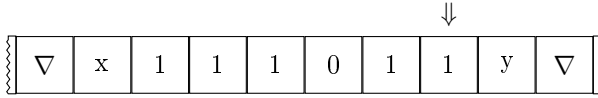
$$K_8 \quad x1110111q_2\nabla \vdash$$

10.



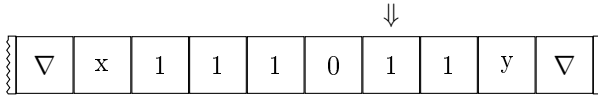
$$K_9 \quad x111011q_31 \vdash$$

11.



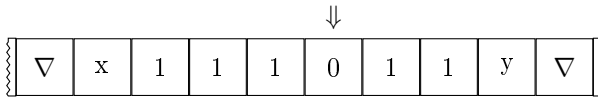
$$K_{10} \quad x11101q_41y \vdash$$

12.



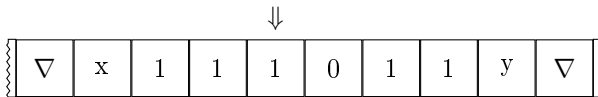
$$K_{11} \quad x1110q_511y \vdash$$

13.



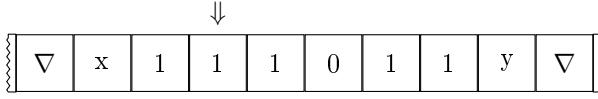
$$K_{12} \quad x111q_5011y \vdash$$

14.

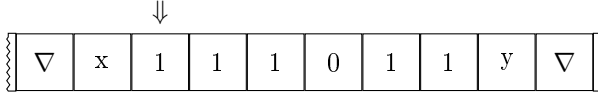


$$K_{13} \quad x11q_51011y \vdash$$

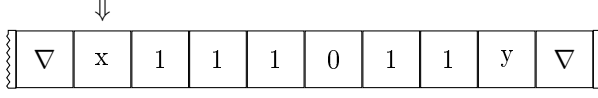
15.

 $K_{14} \quad x1q_511011y \vdash$

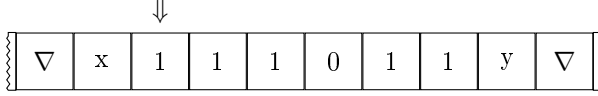
16.

 $K_{15} \quad xq_5111011y \vdash$

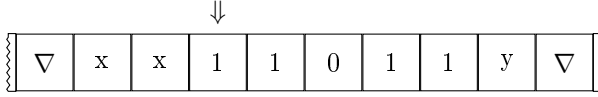
17.

 $K_{16} \quad q_5x111011y \vdash$

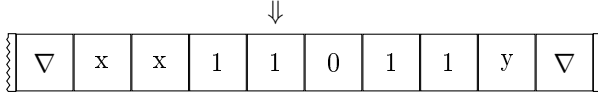
18.

 $K_{17} \quad xq_0111011y \vdash$

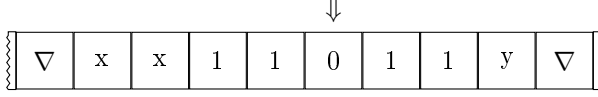
19.

 $K_{18} \quad xxq_111011y \vdash$

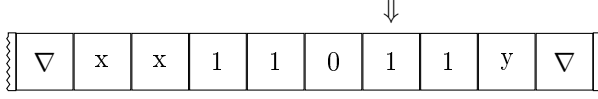
20.

 $K_{19} \quad xx1q_21011y \vdash$

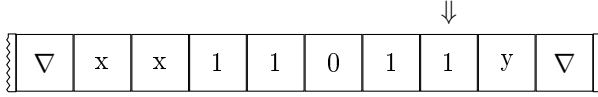
21.

 $K_{20} \quad xx11q_2011y \vdash$

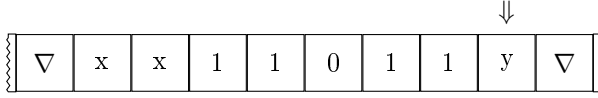
22.

 $K_{21} \quad xx110q_211y \vdash$

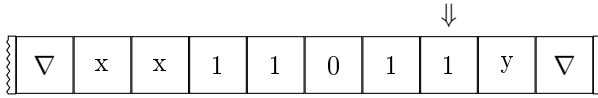
23.

 $K_{22} \quad xx1101q_21y \vdash$

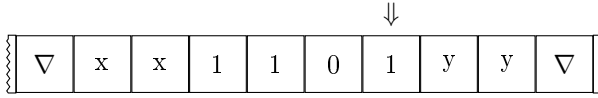
24.

 $K_{23} \quad xx11011q_2y \vdash$

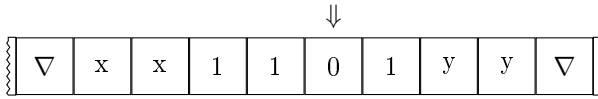
25.

 $K_{24} \quad xx1101q_31y \vdash$

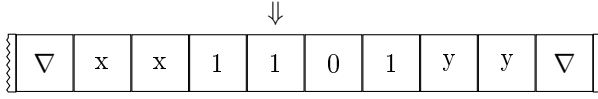
26.

 $K_{25} \quad xx110q_41yy \vdash$

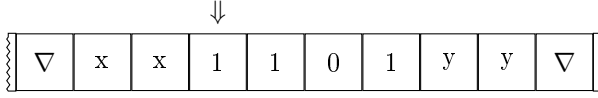
27.

 $K_{26} \quad xx11q_501yy \vdash$

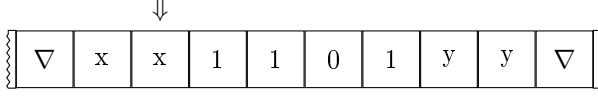
28.

 $K_{27} \quad \text{xx}1q_5101yy \vdash$

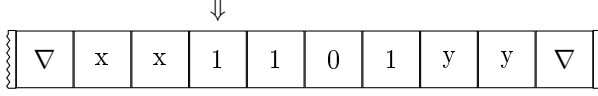
29.

 $K_{28} \quad \text{xx}q_51101yy \vdash$

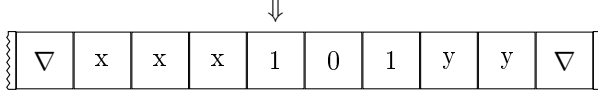
30.

 $K_{29} \quad \text{x}q_5\text{x}1101yy \vdash$

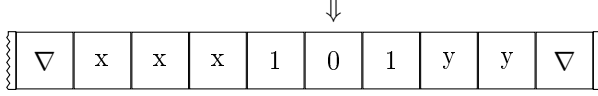
31.

 $K_{30} \quad \text{xx}q_01101yy \vdash$

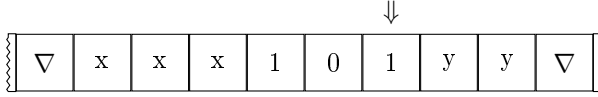
32.

 $K_{31} \quad \text{xxx}q_1101yy \vdash$

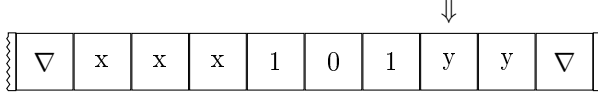
33.

 $K_{32} \quad \text{xxx}1q_201yy \vdash$

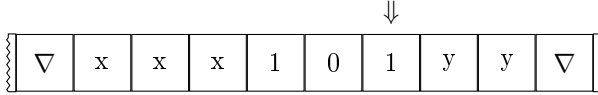
34.

 $K_{33} \quad \text{xxx}10q_21yy \vdash$

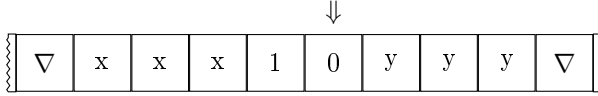
35.

 $K_{34} \quad \text{xxx}101q_2yy \vdash$

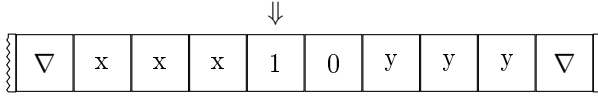
36.

 $K_{35} \quad \text{xxx}10q_31yy \vdash$

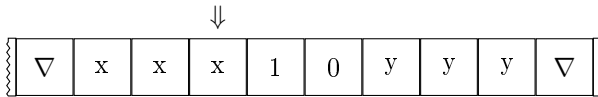
37.

 $K_{36} \quad \text{xxx}1q_40yyy \vdash$

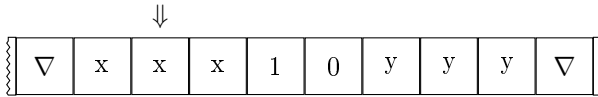
38.

 $K_{37} \quad \text{xxx}q_610yyy \vdash$

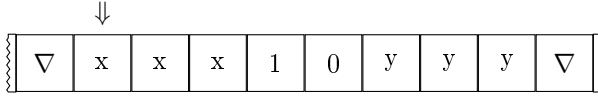
39.

 $K_{38} \quad \text{xx}q_6\text{x}10yyy \vdash$

40.

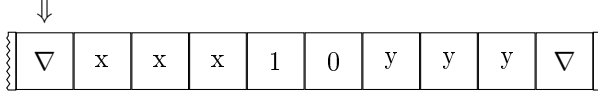
 $K_{39} \quad \text{x}q_6\text{xx}10yyy \vdash$

41.



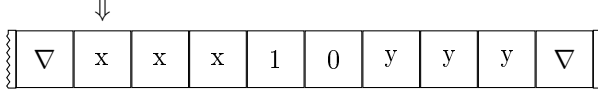
$K_{40} \quad q_6 \text{xxx10yyy} \vdash$

42.



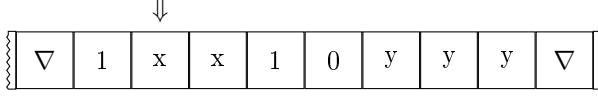
$K_{41} \quad q_6 \nabla \text{xxx10yyy} \vdash$

43.



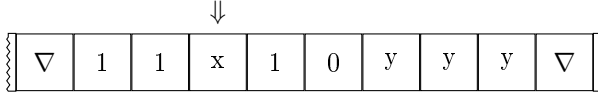
$K_{42} \quad q_9 \text{xxx10yyy} \vdash$

44.



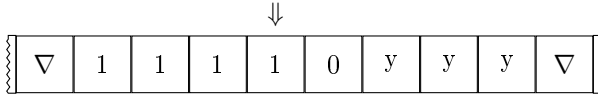
$K_{43} \quad 1q_9 \text{xx10yyy} \vdash$

45.



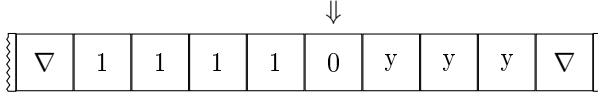
$K_{44} \quad 11q_9 \text{x10yyy} \vdash$

46.



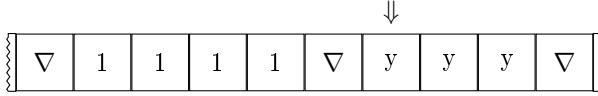
$K_{45} \quad 111q_9 \text{10yyy} \vdash$

47.



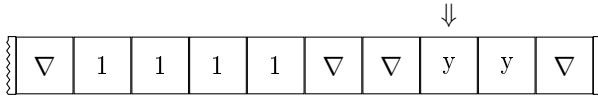
$K_{46} \quad 1111q_9 \text{0yyy} \vdash$

48.



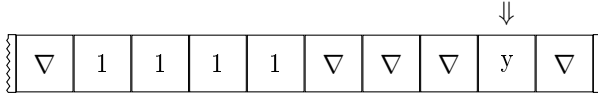
$K_{47} \quad 1111 \nabla q_9 \text{yyy} \vdash$

49.



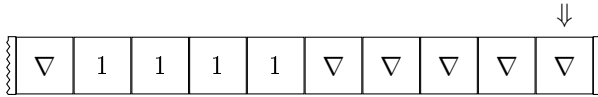
$K_{48} \quad 1111 \nabla \nabla q_9 \text{yy} \vdash$

50.



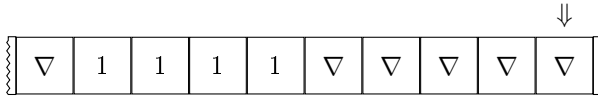
$K_{49} \quad 1111 \nabla \nabla \nabla q_9 \text{y} \vdash$

51.



$K_{50} \quad 1111 \nabla \nabla \nabla \nabla q_9 \nabla \vdash$

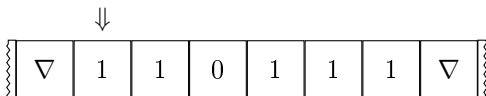
52.



$K_{51} \quad 1111 \nabla \nabla \nabla \nabla q_{10} \nabla$

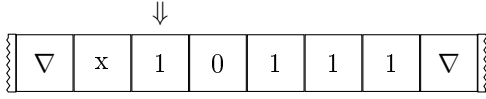
1.11.2 max(1, 2)

1.



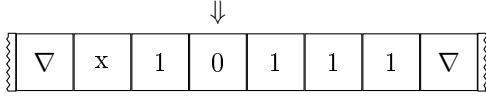
$K_0 \quad q_0 \text{110111} \vdash$

2.



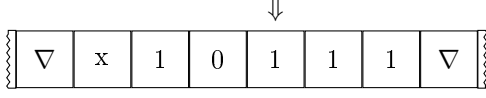
$$K_1 \quad xq_1 10111 \vdash$$

3.



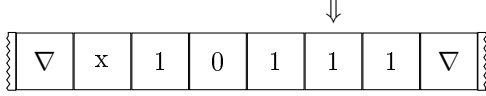
$$K_2 \quad x1q_2 0111 \vdash$$

4.



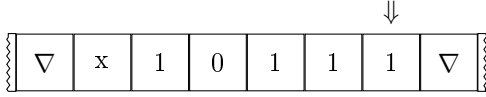
$$K_3 \quad x10q_2 111 \vdash$$

5.



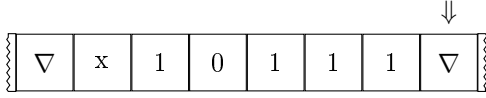
$$K_4 \quad x101q_2 11 \vdash$$

6.



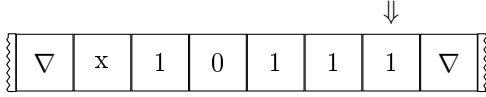
$$K_5 \quad x1011q_2 1 \vdash$$

7.



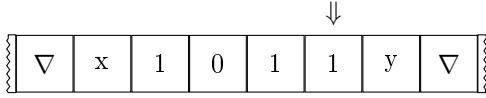
$$K_6 \quad x10111q_2 \nabla \vdash$$

8.



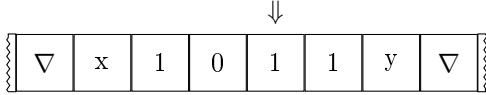
$$K_7 \quad x1011q_3 1 \vdash$$

9.



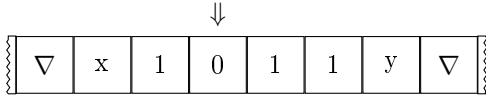
$$K_8 \quad x101q_4 1y \vdash$$

10.



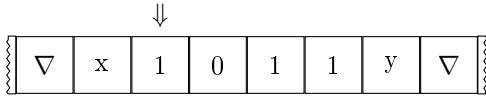
$$K_9 \quad x10q_5 11y \vdash$$

11.



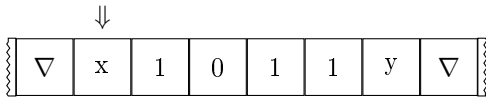
$$K_{10} \quad x1q_5 011y \vdash$$

12.



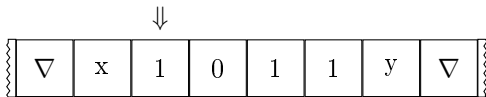
$$K_{11} \quad xq_5 1011y \vdash$$

13.



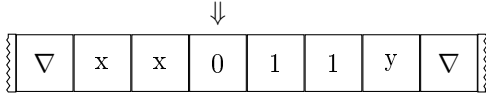
$$K_{12} \quad q_5 x 1011y \vdash$$

14.



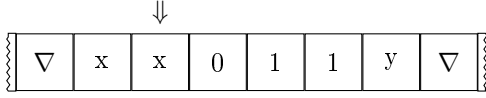
$$K_{13} \quad xq_0 1011y \vdash$$

15.



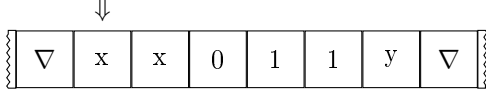
$$K_{14} \quad xxq_1 011y \vdash$$

16.



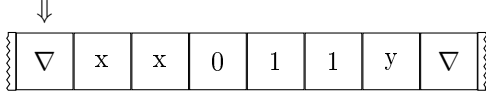
$$K_{15} \quad xq_8 x 011y \vdash$$

17.



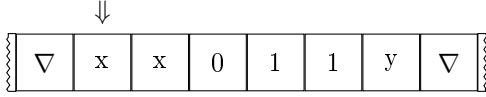
$$K_{16} \quad q_8 xx 011y \vdash$$

18.



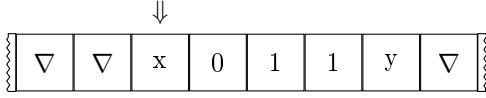
$$K_{17} \quad q_8 \nabla xx 011y \vdash$$

19.



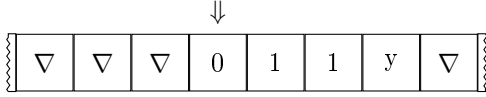
$$K_{18} \quad q_7 xx 011y \vdash$$

20.



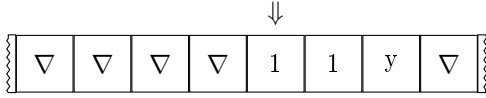
$$K_{19} \quad q_7 x 011y \vdash$$

21.



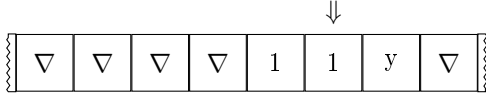
$$K_{20} \quad q_7 011y \vdash$$

22.



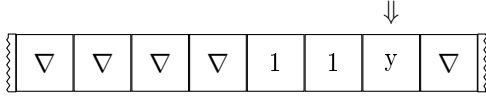
$$K_{21} \quad q_7 11y \vdash$$

23.



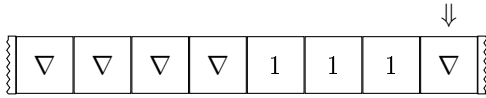
$$K_{22} \quad 1q_7 1y \vdash$$

24.



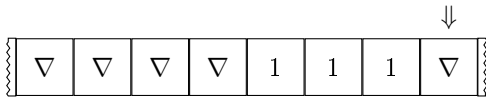
$$K_{23} \quad 11q_7 y \vdash$$

25.



$$K_{24} \quad 111q_7 \nabla \vdash$$

26.



$$K_{25} \quad 111q_{10} \nabla$$

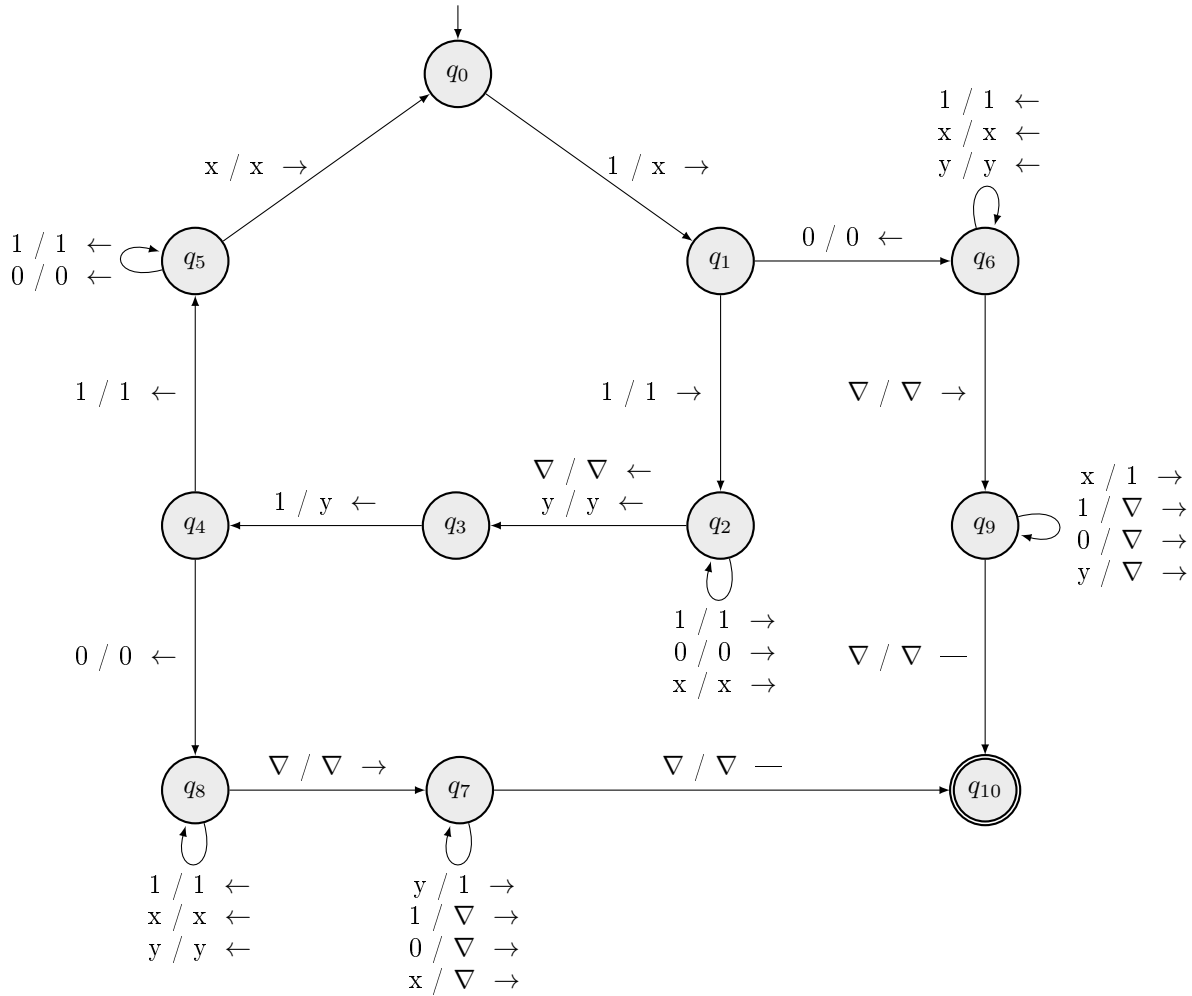
1.12 Zadanie 1.12

Zaprojektuj maszynę Turinga, które oblicza funkcję minimum dla liczb naturalnych m i n w reprezentacji unarnej, czyli

$$(21) \quad f(m, n) = \min(m, n).$$

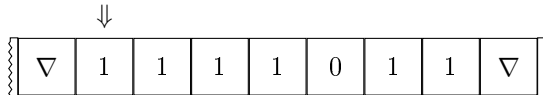
Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(22) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_8, q_9, q_{10}\}, \{1, 0\}, \{1, 0, x, y, \nabla\}, \delta, q_0, \nabla, \{q_{10}\})$$



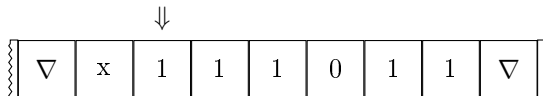
1.12.1 $\min(3, 1)$

1.



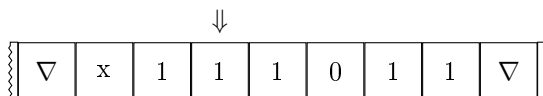
$K_0 \quad q_0 1111011 \vdash$

2.



$K_1 \quad x q_1 111011 \vdash$

3.



$K_2 \quad x 1 q_2 11011 \vdash$

4. \Downarrow

∇	x	1	1	1	0	1	1	∇
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 $K_3 \quad x11q_21011 \vdash$
5. \Downarrow

∇	x	1	1	1	0	1	1	∇
----------	---	---	---	---	---	---	---	----------

 $K_4 \quad x111q_2011 \vdash$
6. \Downarrow

∇	x	1	1	1	0	1	1	∇
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 $K_5 \quad x1110q_211 \vdash$
7. \Downarrow

∇	x	1	1	1	0	1	1	∇
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 $K_6 \quad x11101q_21 \vdash$
8. \Downarrow

∇	x	1	1	1	0	1	1	∇
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 $K_7 \quad x111011q_2\nabla \vdash$
9. \Downarrow

∇	x	1	1	1	0	1	1	∇
----------	---	---	---	---	---	---	---	----------

 $K_8 \quad x11101q_31 \vdash$
10. \Downarrow

∇	x	1	1	1	0	1	y	∇
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 $K_9 \quad x1110q_41y \vdash$
11. \Downarrow

∇	x	1	1	1	0	1	y	∇
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 $K_{10} \quad x111q_501y \vdash$
12. \Downarrow

∇	x	1	1	1	0	1	y	∇
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 $K_{11} \quad x11q_5101y \vdash$
13. \Downarrow

∇	x	1	1	1	0	1	y	∇
----------	---	---	---	---	---	---	---	----------

 $K_{12} \quad x1q_51101y \vdash$
14. \Downarrow

∇	x	1	1	1	0	1	y	∇
----------	---	---	---	---	---	---	---	----------

 $K_{13} \quad xq_511101y \vdash$
15. \Downarrow

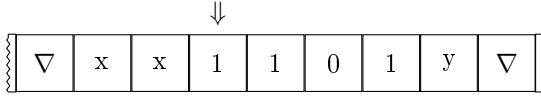
∇	x	1	1	1	0	1	y	∇
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 $K_{14} \quad q_5x11101y \vdash$
16. \Downarrow

∇	x	1	1	1	0	1	y	∇
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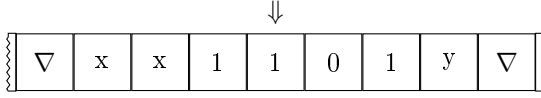
 $K_{15} \quad xq_011101y \vdash$

17.



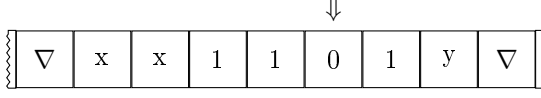
$$K_{16} \quad xxq_11101y \vdash$$

18.



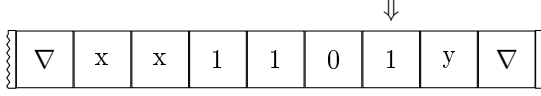
$$K_{17} \quad xx1q_2101y \vdash$$

19.



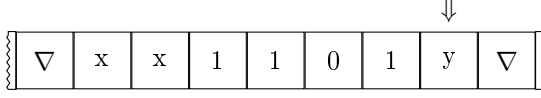
$$K_{18} \quad xx11q_201y \vdash$$

20.



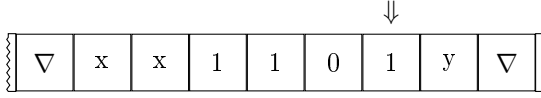
$$K_{19} \quad xx110q_21y \vdash$$

21.



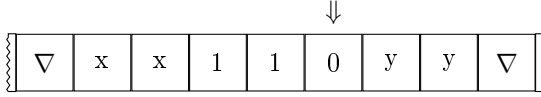
$$K_{20} \quad xx1101q_2y \vdash$$

22.



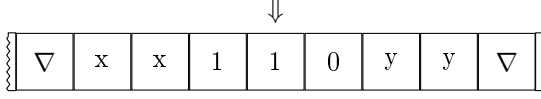
$$K_{21} \quad xx110q_31y \vdash$$

23.



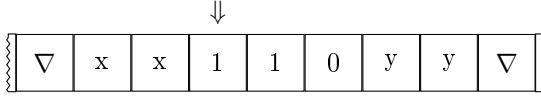
$$K_{22} \quad xx11q_40yy \vdash$$

24.



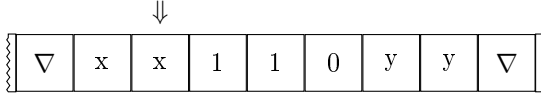
$$K_{23} \quad xx1q_810yy \vdash$$

25.



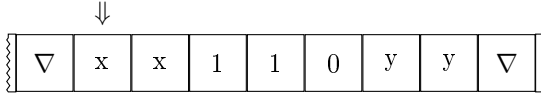
$$K_{24} \quad xxq_8110yy \vdash$$

26.



$$K_{25} \quad xq_8x110yy \vdash$$

27.



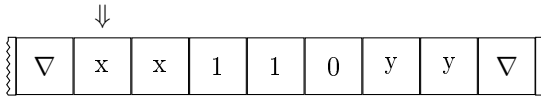
$$K_{26} \quad q_8xx110yy \vdash$$

28.



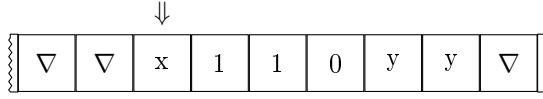
$$K_{27} \quad q_8\nabla xx110yy \vdash$$

29.



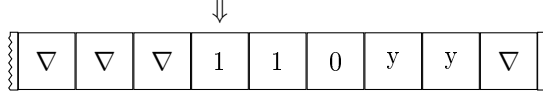
$$K_{28} \quad q_7xx110yy \vdash$$

30.



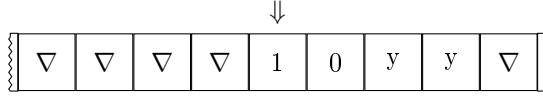
$K_{29} \quad q_7x110yy \vdash$

31.



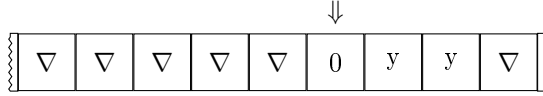
$K_{30} \quad q_7110yy \vdash$

32.



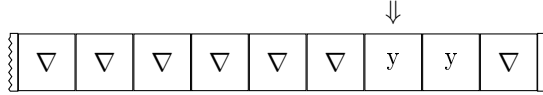
$K_{31} \quad q_710yy \vdash$

33.



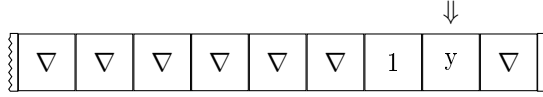
$K_{32} \quad q_70yy \vdash$

34.



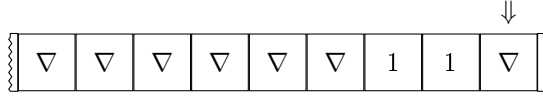
$K_{33} \quad q_7yy \vdash$

35.



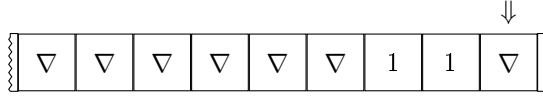
$K_{34} \quad 1q_7y \vdash$

36.



$K_{35} \quad 11q_7\nabla \vdash$

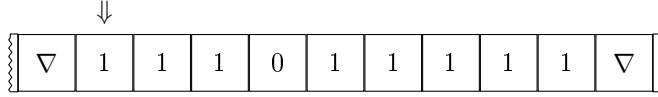
37.



$K_{36} \quad 11q_{10}\nabla$

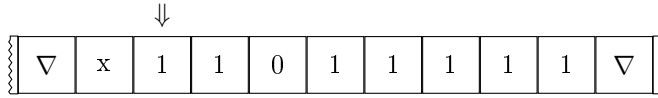
1.12.2 min(2, 4)

1.



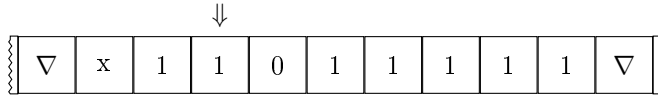
$K_0 \quad q_0111011111 \vdash$

2.



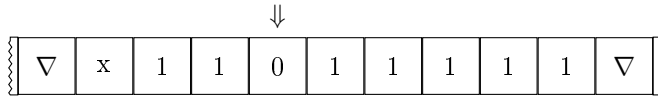
$K_1 \quad xq_1110111111 \vdash$

3.



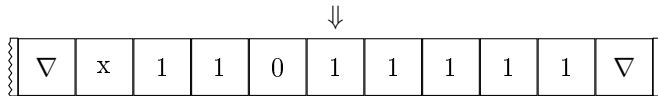
$K_2 \quad x1q_210111111 \vdash$

4.



$K_3 \quad x11q_20111111 \vdash$

5.



$K_4 \quad x110q_211111 \vdash$

6.

 \Downarrow

∇	x	1	1	0	1	1	1	1	1	∇
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 $K_5 \quad x1101q_21111 \vdash$

7.

 \Downarrow

∇	x	1	1	0	1	1	1	1	1	∇
----------	---	---	---	---	---	---	---	---	---	----------

 $K_6 \quad x11011q_2111 \vdash$

8.

 \Downarrow

∇	x	1	1	0	1	1	1	1	1	∇
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 $K_7 \quad x110111q_211 \vdash$

9.

 \Downarrow

∇	x	1	1	0	1	1	1	1	1	∇
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 $K_8 \quad x1101111q_21 \vdash$

10.

 \Downarrow

∇	x	1	1	0	1	1	1	1	1	∇
----------	---	---	---	---	---	---	---	---	---	----------

 $K_9 \quad x11011111q_2\nabla \vdash$

11.

 \Downarrow

∇	x	1	1	0	1	1	1	1	1	∇
----------	---	---	---	---	---	---	---	---	---	----------

 $K_{10} \quad x11011111q_31 \vdash$

12.

 \Downarrow

∇	x	1	1	0	1	1	1	1	y	∇
----------	---	---	---	---	---	---	---	---	---	----------

 $K_{11} \quad x110111q_41y \vdash$

13.

 \Downarrow

∇	x	1	1	0	1	1	1	1	y	∇
----------	---	---	---	---	---	---	---	---	---	----------

 $K_{12} \quad x11011q_511y \vdash$

14.

 \Downarrow

∇	x	1	1	0	1	1	1	1	y	∇
----------	---	---	---	---	---	---	---	---	---	----------

 $K_{13} \quad x1101q_5111y \vdash$

15.

 \Downarrow

∇	x	1	1	0	1	1	1	1	y	∇
----------	---	---	---	---	---	---	---	---	---	----------

 $K_{14} \quad x110q_51111y \vdash$

16.

 \Downarrow

∇	x	1	1	0	1	1	1	1	y	∇
----------	---	---	---	---	---	---	---	---	---	----------

 $K_{15} \quad x11q_501111y \vdash$

17.

 \Downarrow

∇	x	1	1	0	1	1	1	1	y	∇
----------	---	---	---	---	---	---	---	---	---	----------

 $K_{16} \quad x1q_5101111y \vdash$

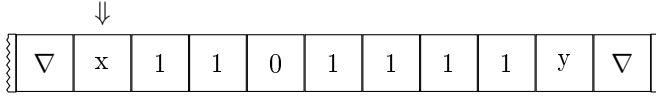
18.

 \Downarrow

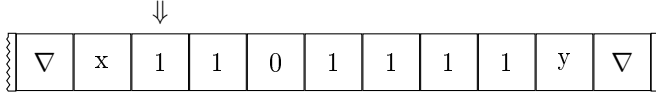
∇	x	1	1	0	1	1	1	1	y	∇
----------	---	---	---	---	---	---	---	---	---	----------

 $K_{17} \quad xq_51101111y \vdash$

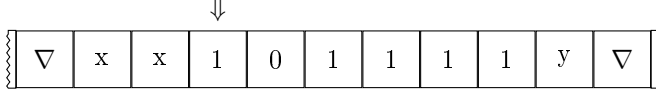
19.

 $K_{18} \quad q_5 x 1 1 0 1 1 1 1 y \vdash$

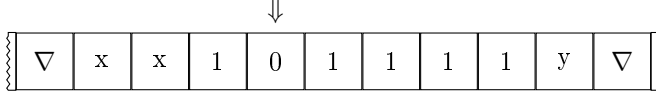
20.

 $K_{19} \quad x q_0 1 1 0 1 1 1 1 y \vdash$

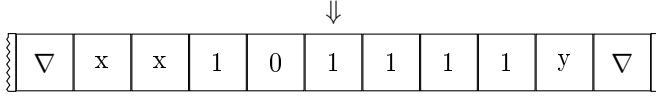
21.

 $K_{20} \quad x x q_1 1 0 1 1 1 1 y \vdash$

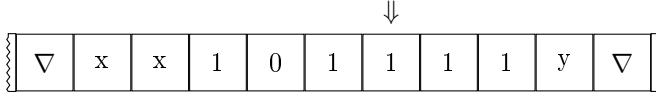
22.

 $K_{21} \quad x x 1 q_2 0 1 1 1 1 y \vdash$

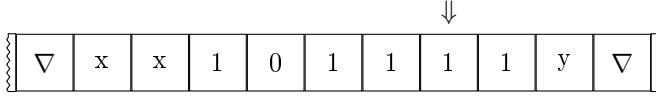
23.

 $K_{22} \quad x x 1 0 q_2 1 1 1 1 y \vdash$

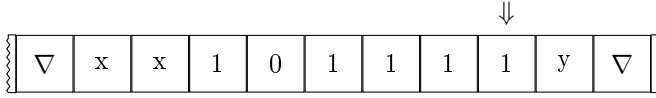
24.

 $K_{23} \quad x x 1 0 1 q_2 1 1 1 y \vdash$

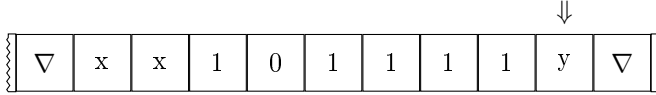
25.

 $K_{24} \quad x x 1 0 1 1 q_2 1 1 y \vdash$

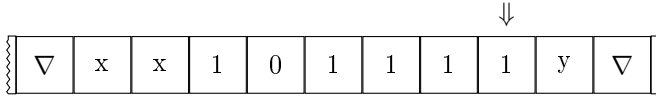
26.

 $K_{25} \quad x x 1 0 1 1 1 q_2 1 y \vdash$

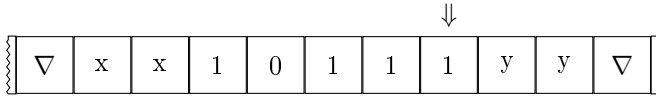
27.

 $K_{26} \quad x x 1 0 1 1 1 1 q_2 y \vdash$

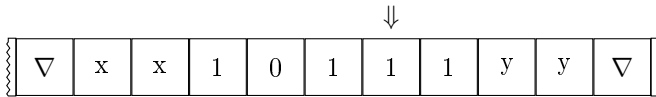
28.

 $K_{27} \quad x x 1 0 1 1 1 q_3 1 y \vdash$

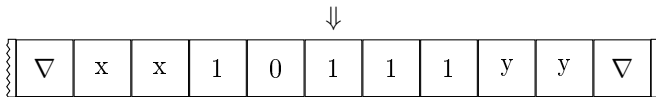
29.

 $K_{28} \quad x x 1 0 1 1 q_4 1 y y \vdash$

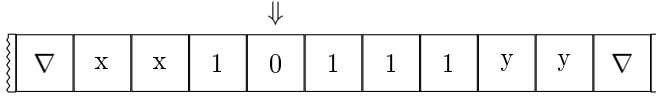
30.

 $K_{29} \quad x x 1 0 1 q_5 1 1 y y \vdash$

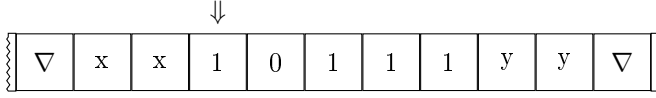
31.

 $K_{30} \quad x x 1 0 q_5 1 1 1 y y \vdash$

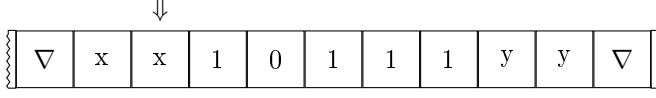
32.

 $K_{31} \quad \text{xx}1q_50111yy \vdash$

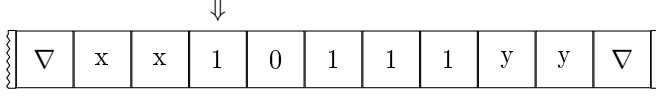
33.

 $K_{32} \quad \text{xx}q_510111yy \vdash$

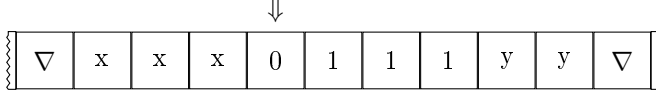
34.

 $K_{33} \quad \text{x}q_5\text{x}10111yy \vdash$

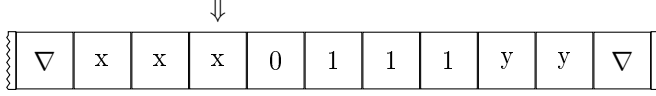
35.

 $K_{34} \quad \text{xx}q_010111yy \vdash$

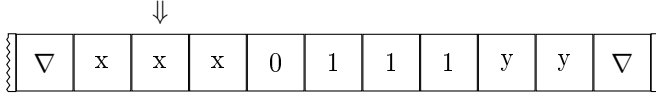
36.

 $K_{35} \quad \text{xxx}q_10111yy \vdash$

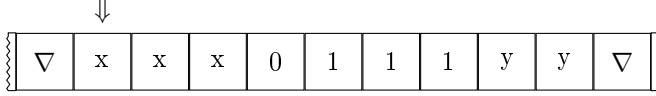
37.

 $K_{36} \quad \text{xx}q_6\text{x}0111yy \vdash$

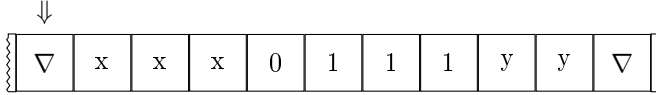
38.

 $K_{37} \quad \text{x}q_6\text{xx}0111yy \vdash$

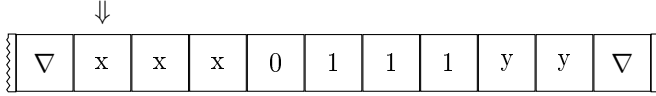
39.

 $K_{38} \quad q_6\text{xxx}0111yy \vdash$

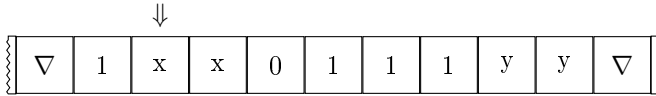
40.

 $K_{39} \quad q_6\nabla\text{xxx}0111yy \vdash$

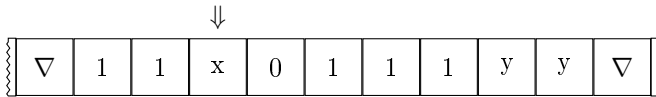
41.

 $K_{40} \quad q_9\text{xxx}0111yy \vdash$

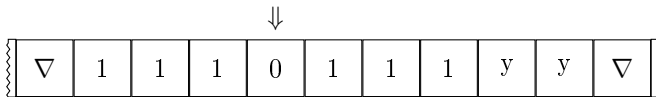
42.

 $K_{41} \quad 1q_9\text{xx}0111yy \vdash$

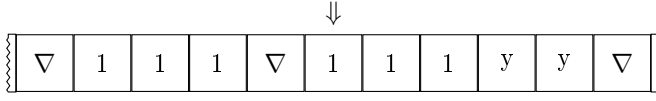
43.

 $K_{42} \quad 11q_9\text{x}0111yy \vdash$

44.

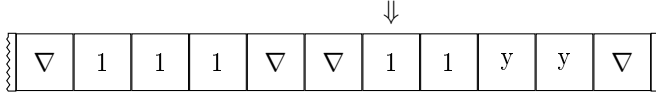
 $K_{43} \quad 111q_90111yy \vdash$

45.



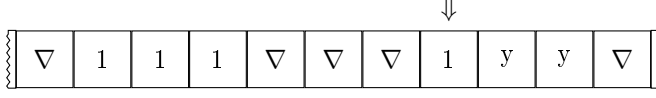
$$K_{44} \quad 111\nabla q_9 111yy \vdash$$

46.



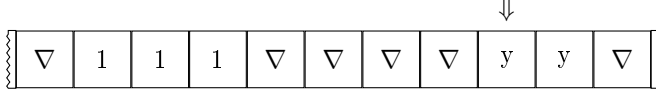
$$K_{45} \quad 111\nabla\nabla q_9 11yy \vdash$$

47.



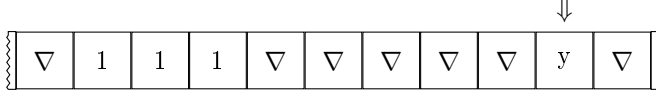
$$K_{46} \quad 111\nabla\nabla\nabla q_9 1yy \vdash$$

48.



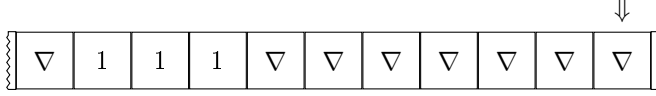
$$K_{47} \quad 111\nabla\nabla\nabla\nabla q_9 yy \vdash$$

49.



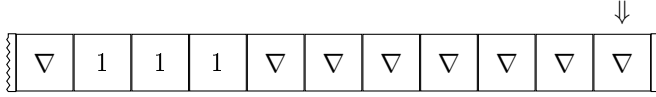
$$K_{48} \quad 111\nabla\nabla\nabla\nabla\nabla q_9 y \vdash$$

50.



$$K_{49} \quad 111\nabla\nabla\nabla\nabla\nabla\nabla q_9 \nabla \vdash$$

51.



$$K_{50} \quad 111\nabla\nabla\nabla\nabla\nabla\nabla\nabla q_{10} \nabla$$

2 Maszyny Turinga obliczające funkcje w alfabecie binarnym

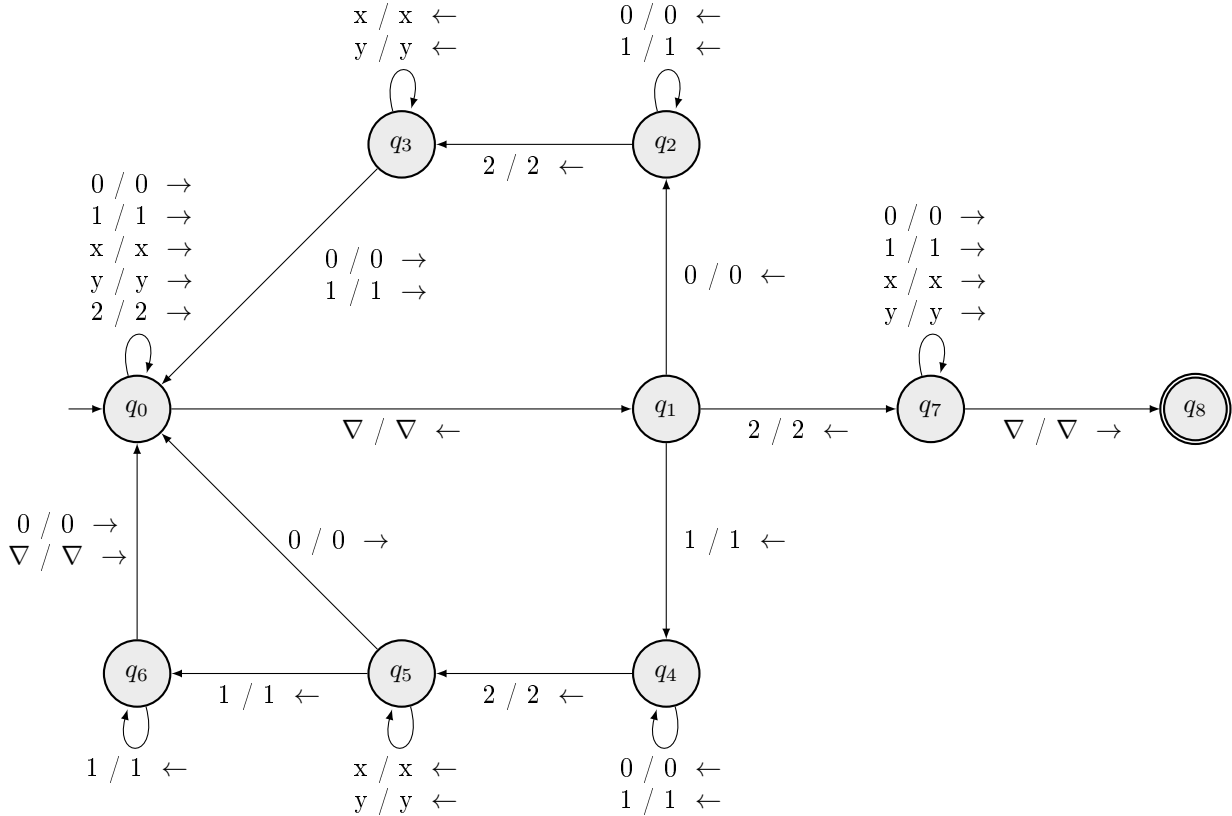
2.1 Zadanie 1.18

Zaprojektuj maszynę Turinga, która oblicza funkcję dodawania

$$(23) \quad f(m, n) = m + n.$$

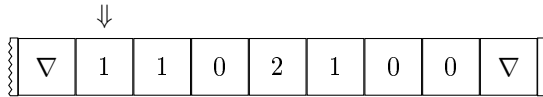
dla liczby naturalnej n w reprezentacji binarnej. Za separator przyjmij 2. Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia, w tym dodaj $3 + 2$ (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(24) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_8\}, \{0, 1, 2\}, \{0, 1, 2, x, y, \nabla\}, \delta, q_0, \nabla, \{q_8\})$$



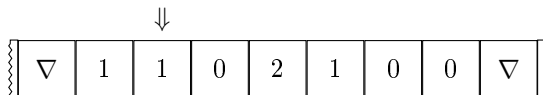
2.1.1 $f(6, 4)$

1.



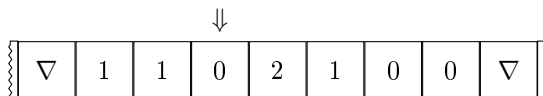
$K_0 \quad q_0 1102100 \vdash$

2.



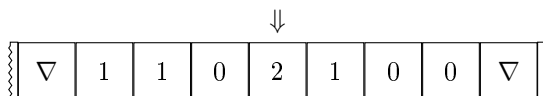
$K_1 \quad 1q_0 102100 \vdash$

3.



$K_2 \quad 11q_0 02100 \vdash$

4.



$K_3 \quad 110q_0 2100 \vdash$

5.

 \Downarrow

∇	1	1	0	2	1	0	0	∇
----------	---	---	---	---	---	---	---	----------

 $K_4 \quad 1102q_0100 \vdash$

6.

 \Downarrow

∇	1	1	0	2	1	0	0	∇
----------	---	---	---	---	---	---	---	----------

 $K_5 \quad 11021q_000 \vdash$

7.

 \Downarrow

∇	1	1	0	2	1	0	0	∇
----------	---	---	---	---	---	---	---	----------

 $K_6 \quad 110210q_00 \vdash$

8.

 \Downarrow

∇	1	1	0	2	1	0	0	∇
----------	---	---	---	---	---	---	---	----------

 $K_7 \quad 1102100q_0\nabla \vdash$

9.

 \Downarrow

∇	1	1	0	2	1	0	0	∇
----------	---	---	---	---	---	---	---	----------

 $K_8 \quad 110210q_10 \vdash$

10.

 \Downarrow

∇	1	1	0	2	1	0	∇	∇
----------	---	---	---	---	---	---	----------	----------

 $K_9 \quad 11021q_20 \vdash$

11.

 \Downarrow

∇	1	1	0	2	1	0	∇	∇
----------	---	---	---	---	---	---	----------	----------

 $K_{10} \quad 1102q_210 \vdash$

12.

 \Downarrow

∇	1	1	0	2	1	0	∇	∇
----------	---	---	---	---	---	---	----------	----------

 $K_{11} \quad 110q_2210 \vdash$

13.

 \Downarrow

∇	1	1	0	2	1	0	∇	∇
----------	---	---	---	---	---	---	----------	----------

 $K_{12} \quad 11q_30210 \vdash$

14.

 \Downarrow

∇	1	1	x	2	1	0	∇	∇
----------	---	---	---	---	---	---	----------	----------

 $K_{13} \quad 11xq_0210 \vdash$

15.

 \Downarrow

∇	1	1	x	2	1	0	∇	∇
----------	---	---	---	---	---	---	----------	----------

 $K_{14} \quad 11x2q_010 \vdash$

16.

 \Downarrow

∇	1	1	x	2	1	0	∇	∇
----------	---	---	---	---	---	---	----------	----------

 $K_{15} \quad 11x21q_00 \vdash$

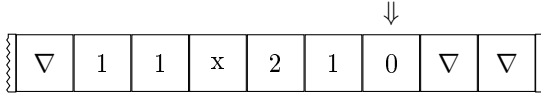
17.

 \Downarrow

∇	1	1	x	2	1	0	∇	∇
----------	---	---	---	---	---	---	----------	----------

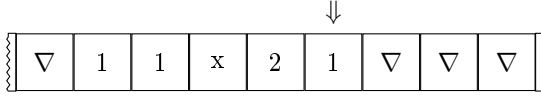
 $K_{16} \quad 11x210q_0\nabla \vdash$

18.



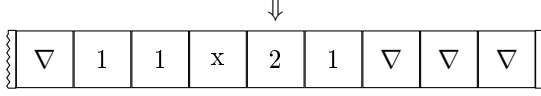
$$K_{17} \quad 11x21q_10 \vdash$$

19.



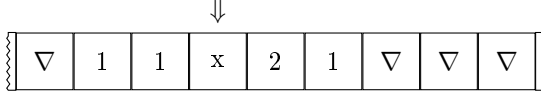
$$K_{18} \quad 11x2q_21 \vdash$$

20.



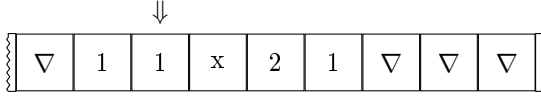
$$K_{19} \quad 11xq_221 \vdash$$

21.



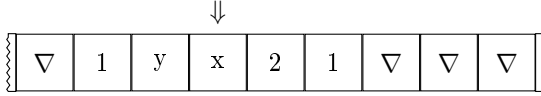
$$K_{20} \quad 11q_3x21 \vdash$$

22.



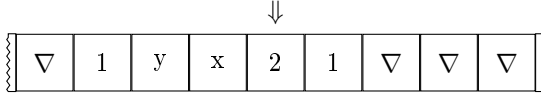
$$K_{21} \quad 1q_31x21 \vdash$$

23.



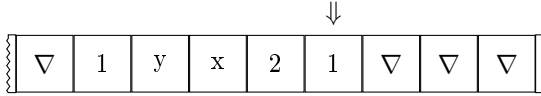
$$K_{22} \quad 1yq_0x21 \vdash$$

24.



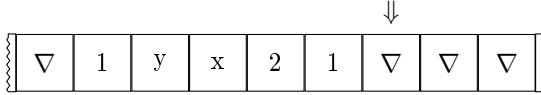
$$K_{23} \quad 1yxq_021 \vdash$$

25.



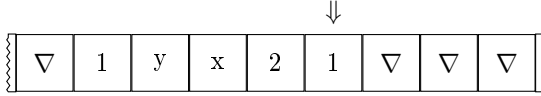
$$K_{24} \quad 1yx2q_01 \vdash$$

26.



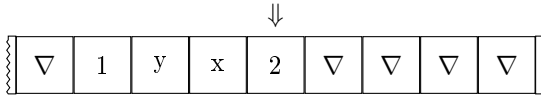
$$K_{25} \quad 1yx21q_0\nabla \vdash$$

27.



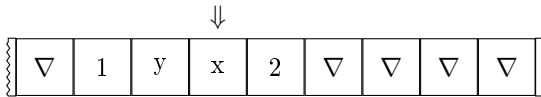
$$K_{26} \quad 1yx2q_11 \vdash$$

28.



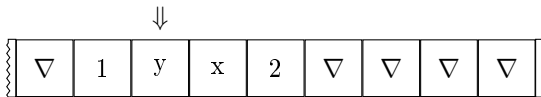
$$K_{27} \quad 1yxq_42 \vdash$$

29.



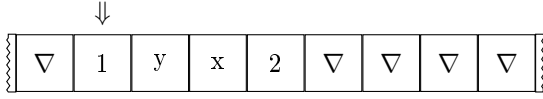
$$K_{28} \quad 1yq_5x2 \vdash$$

30.



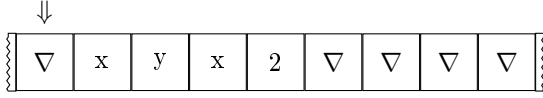
$$K_{29} \quad 1q_5yx2 \vdash$$

31.



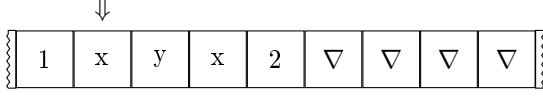
$K_{30} \quad q_5 1yx2 \vdash$

32.



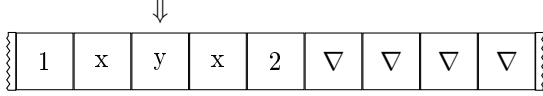
$K_{31} \quad q_6 \nabla xyx2 \vdash$

33.



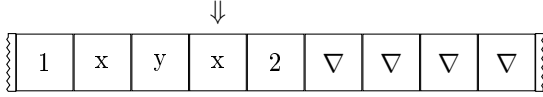
$K_{32} \quad 1q_0xyx2 \vdash$

34.



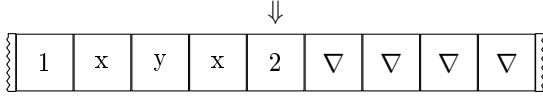
$K_{33} \quad 1xq_0yx2 \vdash$

35.



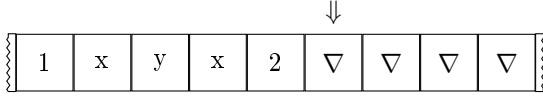
$K_{34} \quad 1xyq_0x2 \vdash$

36.



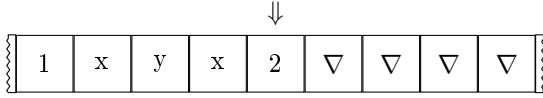
$K_{35} \quad 1xyxq_02 \vdash$

37.



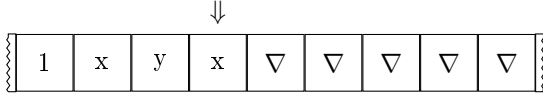
$K_{36} \quad 1xyx2q_0\nabla \vdash$

38.



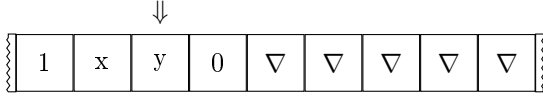
$K_{37} \quad 1xyxq_12 \vdash$

39.



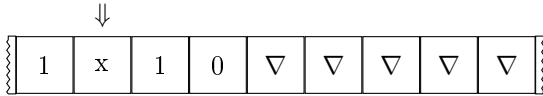
$K_{38} \quad 1xyq_7x \vdash$

40.



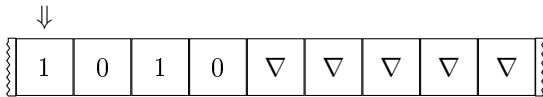
$K_{39} \quad 1xq_7y0 \vdash$

41.



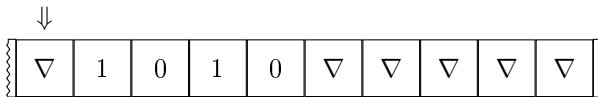
$K_{40} \quad 1q_7x10 \vdash$

42.



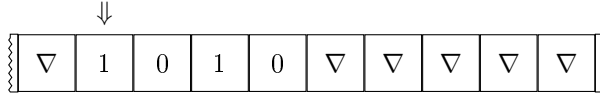
$K_{41} \quad q_71010 \vdash$

43.

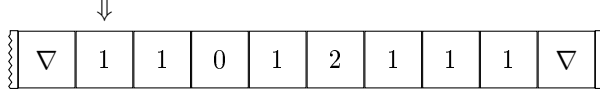


$K_{42} \quad q_7\nabla1010 \vdash$

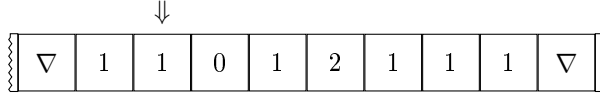
44.

 $K_{43} \quad q_8 1010$ **2.1.1.2 f(13, 7)**

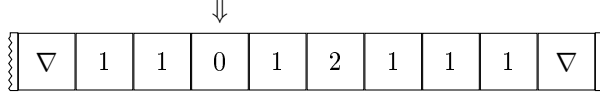
1.

 $K_0 \quad q_0 11012111 \vdash$

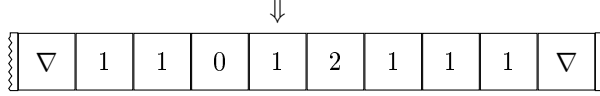
2.

 $K_1 \quad 1q_0 1012111 \vdash$

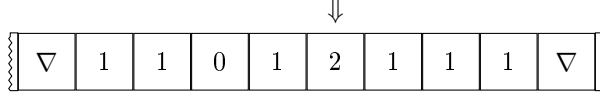
3.

 $K_2 \quad 11q_0 012111 \vdash$

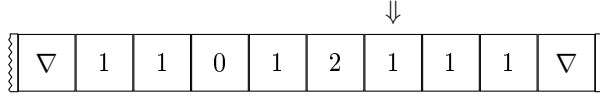
4.

 $K_3 \quad 110q_0 12111 \vdash$

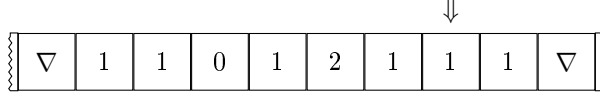
5.

 $K_4 \quad 1101q_0 2111 \vdash$

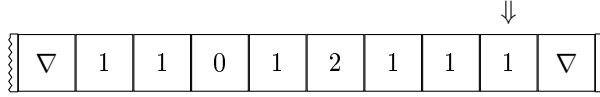
6.

 $K_5 \quad 11012q_0 111 \vdash$

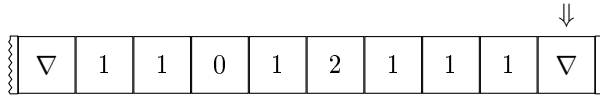
7.

 $K_6 \quad 110121q_0 11 \vdash$

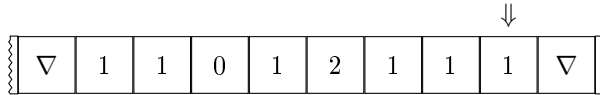
8.

 $K_7 \quad 1101211q_0 1 \vdash$

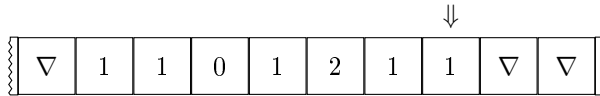
9.

 $K_8 \quad 11012111q_0 \nabla \vdash$

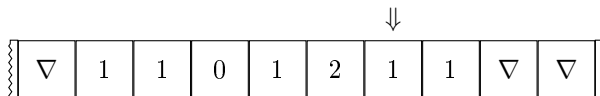
10.

 $K_9 \quad 1101211q_1 1 \vdash$

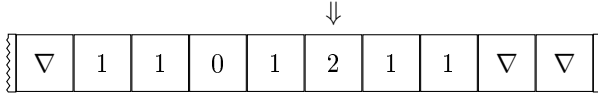
11.

 $K_{10} \quad 110121q_4 1 \vdash$

12.

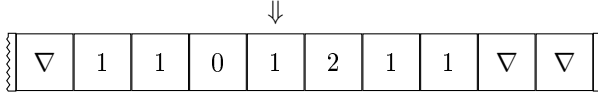
 $K_{11} \quad 11012q_4 11 \vdash$

13.



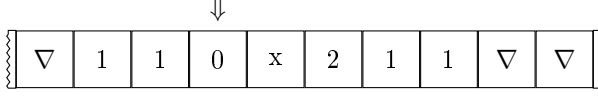
$$K_{12} \quad 1101q_4211 \quad \vdash$$

14.



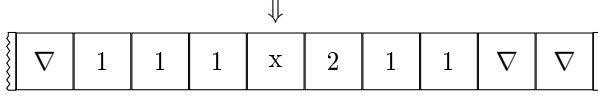
$$K_{13} \quad 110q_51211 \quad \vdash$$

15.



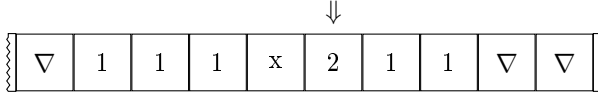
$$K_{14} \quad 11q_60x211 \quad \vdash$$

16.



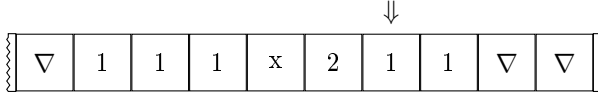
$$K_{15} \quad 111q_0x211 \quad \vdash$$

17.



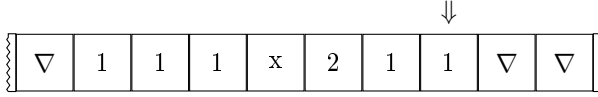
$$K_{16} \quad 111xq_0211 \quad \vdash$$

18.



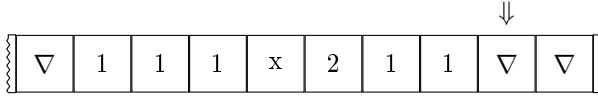
$$K_{17} \quad 111x2q_011 \quad \vdash$$

19.



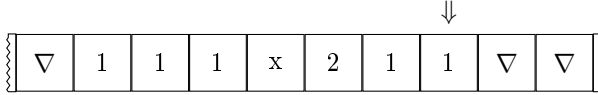
$$K_{18} \quad 111x21q_01 \quad \vdash$$

20.



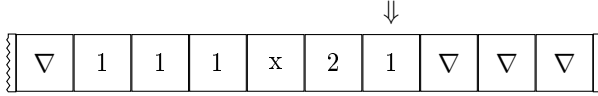
$$K_{19} \quad 111x211q_0\nabla \quad \vdash$$

21.



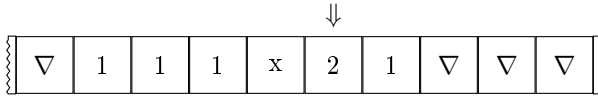
$$K_{20} \quad 111x21q_11 \quad \vdash$$

22.



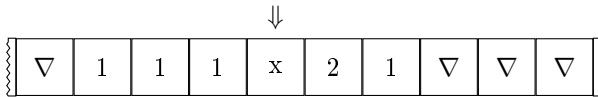
$$K_{21} \quad 111x2q_41 \quad \vdash$$

23.



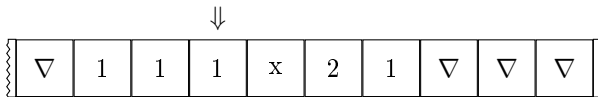
$$K_{22} \quad 111xq_421 \quad \vdash$$

24.



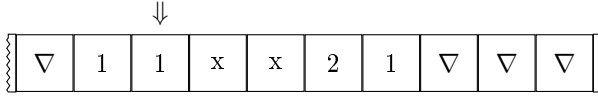
$$K_{23} \quad 111q_5x21 \quad \vdash$$

25.



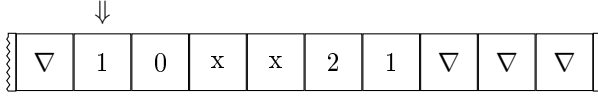
$$K_{24} \quad 11q_51x21 \quad \vdash$$

26.



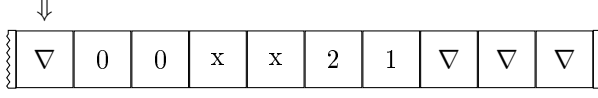
$$K_{25} \quad 1q_61xx21 \quad \vdash$$

27.



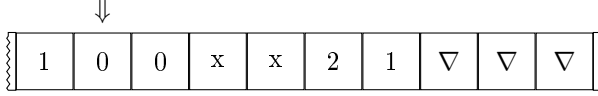
$$K_{26} \quad q_610xx21 \quad \vdash$$

28.



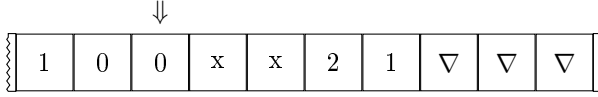
$$K_{27} \quad q_6\nabla 00xx21 \quad \vdash$$

29.



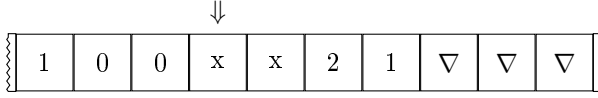
$$K_{28} \quad 1q_000xx21 \quad \vdash$$

30.



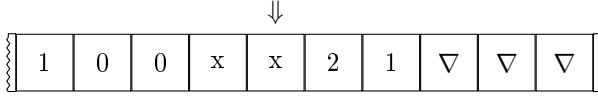
$$K_{29} \quad 10q_00xx21 \quad \vdash$$

31.



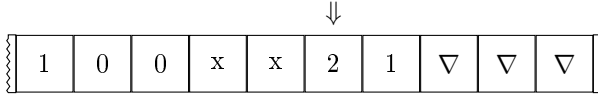
$$K_{30} \quad 100q_0xx21 \quad \vdash$$

32.



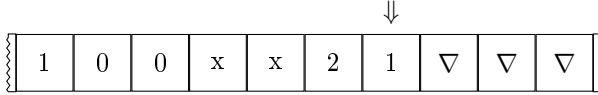
$$K_{31} \quad 100xq_0x21 \quad \vdash$$

33.



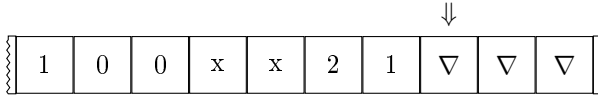
$$K_{32} \quad 100xxq_021 \quad \vdash$$

34.



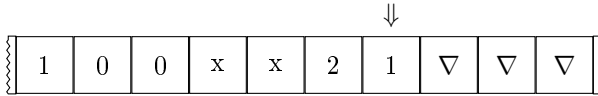
$$K_{33} \quad 100xx2q_01 \quad \vdash$$

35.



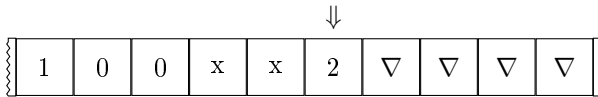
$$K_{34} \quad 100xx21q_0\nabla \quad \vdash$$

36.



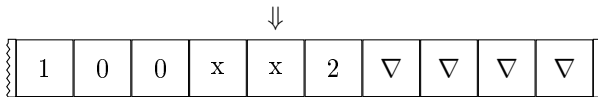
$$K_{35} \quad 100xx2q_11 \quad \vdash$$

37.



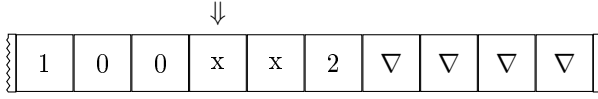
$$K_{36} \quad 100xxq_42 \quad \vdash$$

38.



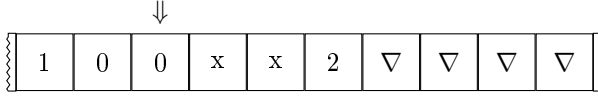
$$K_{37} \quad 100xq_5x2 \quad \vdash$$

39.



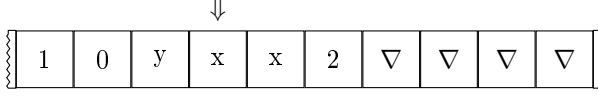
$K_{38} \quad 100q_5xx2 \vdash$

40.



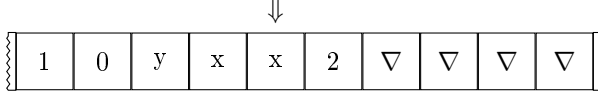
$K_{39} \quad 10q_50xx2 \vdash$

41.



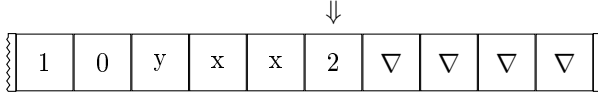
$K_{40} \quad 10yq_0xx2 \vdash$

42.



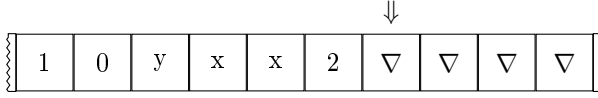
$K_{41} \quad 10yxq_0x2 \vdash$

43.



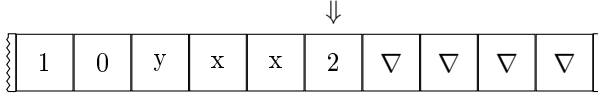
$K_{42} \quad 10yxxq_02 \vdash$

44.



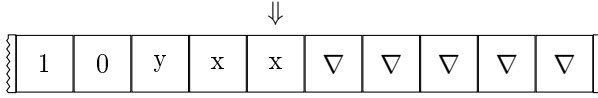
$K_{43} \quad 10yxx2q_0\triangledown \vdash$

45.



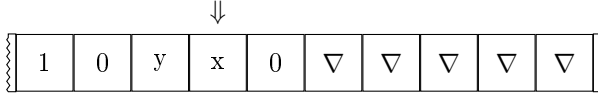
$K_{44} \quad 10yxxq_12 \vdash$

46.



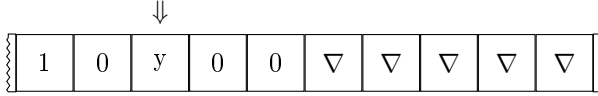
$K_{45} \quad 10yxq_7x \vdash$

47.



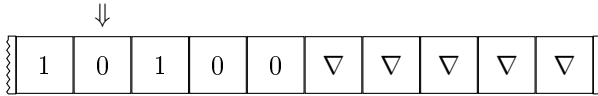
$K_{46} \quad 10yq_7x0 \vdash$

48.



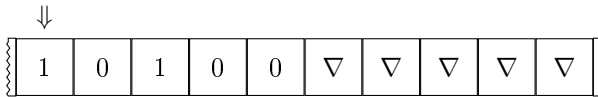
$K_{47} \quad 10q_7y00 \vdash$

49.



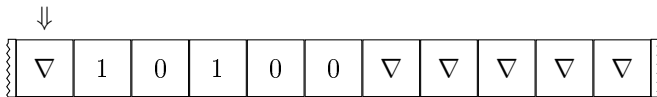
$K_{48} \quad 1q_70100 \vdash$

50.



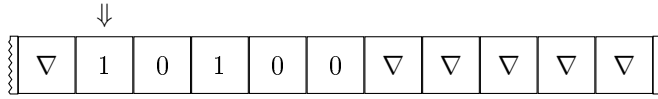
$K_{49} \quad q_710100 \vdash$

51.



$K_{50} \quad q_7\triangledown10100 \vdash$

52.



$K_{51} \quad q_8 10100$

3 Maszyny Turinga akceptujące języki

3.1 Zadanie 1.19

Zaprojektuj maszynę Turinga, która kopiuje wejściowy łańcuch w dla alfabetu $\Sigma = \{a, b\}$. Rozwiązanie może nie zawierać separatora

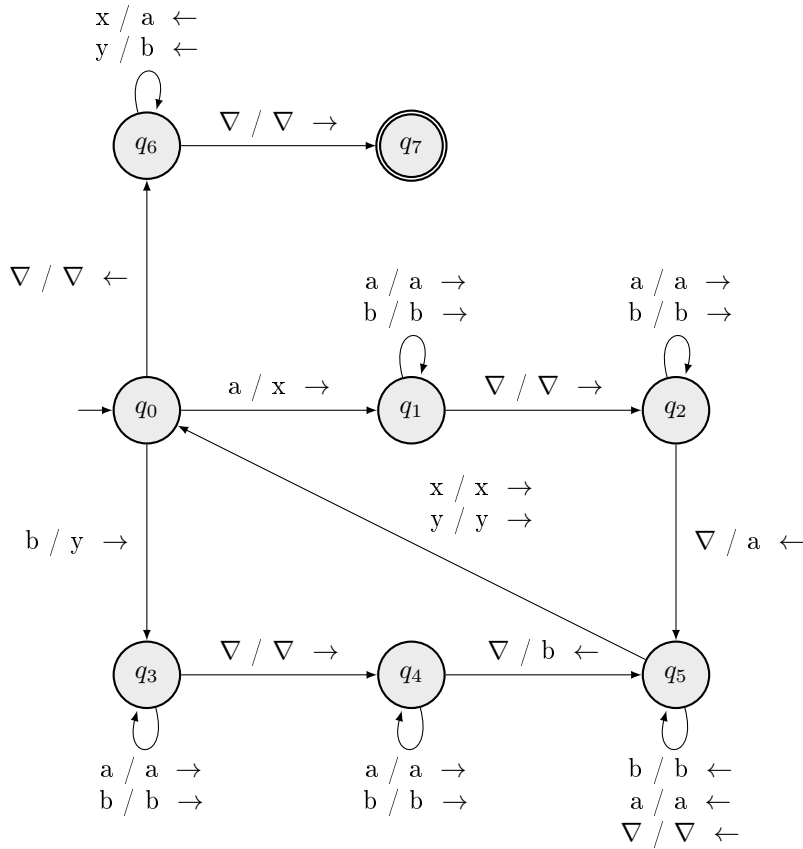
$$(25) \quad q_0 w \vdash^* q_f w w$$

lub może zawierać dowolny separator, na przykład separatorem może być blank, czyli

$$(26) \quad q_0 w \vdash^* q_f w \nabla w$$

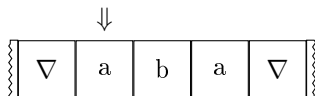
Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(27) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6, q_7\}, \{a, b\}, \{a, b, x, y, \nabla\}, \delta, q_0, \nabla, \{q_7\})$$



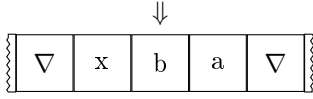
3.1.1 aba

1.



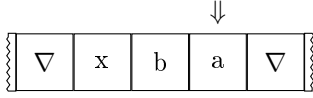
$K_0 \quad q_0 aba \vdash$

2.



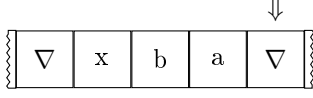
$$K_1 \quad xq_1ba \vdash$$

3.



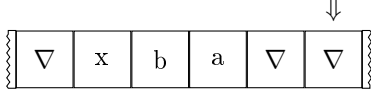
$$K_2 \quad xbq_1a \vdash$$

4.



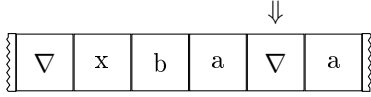
$$K_3 \quad xbaq_1\nabla \vdash$$

5.



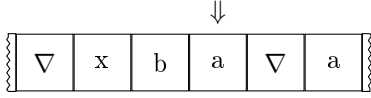
$$K_4 \quad xba\nabla q_2\nabla \vdash$$

6.



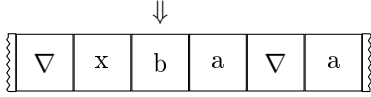
$$K_5 \quad xbaq_5\nabla a \vdash$$

7.



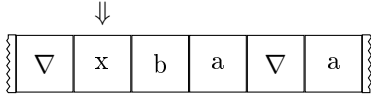
$$K_6 \quad x bq_5a\nabla a \vdash$$

8.



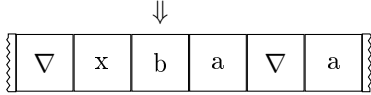
$$K_7 \quad xq_5ba\nabla a \vdash$$

9.



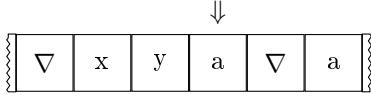
$$K_8 \quad q_5xba\nabla a \vdash$$

10.



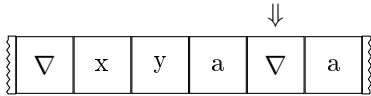
$$K_9 \quad xq_0ba\nabla a \vdash$$

11.



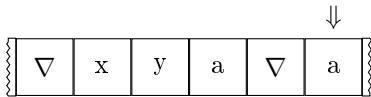
$$K_{10} \quad xyq_3a\nabla a \vdash$$

12.



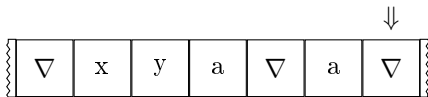
$$K_{11} \quad xyaq_3\nabla a \vdash$$

13.



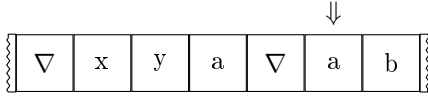
$$K_{12} \quad xya\nabla q_4a \vdash$$

14.



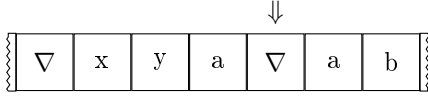
$$K_{13} \quad xya\nabla aq_4\nabla \vdash$$

15.



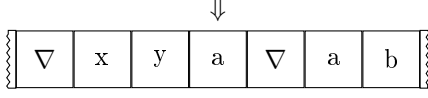
$$K_{14} \quad xya\nabla q_5 ab \vdash$$

16.



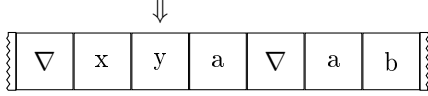
$$K_{15} \quad xyaq_5\nabla ab \vdash$$

17.



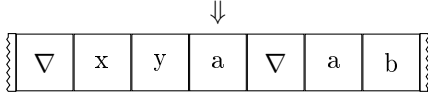
$$K_{16} \quad xyq_5a\nabla ab \vdash$$

18.



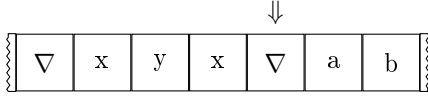
$$K_{17} \quad xq_5ya\nabla ab \vdash$$

19.



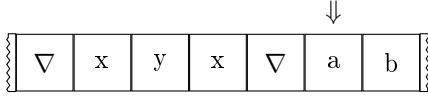
$$K_{18} \quad xyq_0a\nabla ab \vdash$$

20.



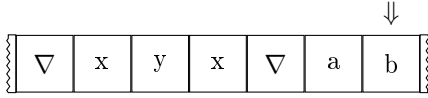
$$K_{19} \quad xyxq_1\nabla ab \vdash$$

21.



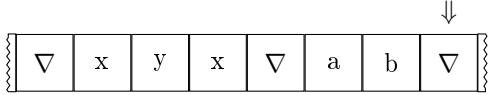
$$K_{20} \quad xyx\nabla q_2 ab \vdash$$

22.



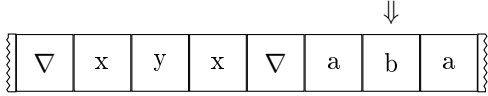
$$K_{21} \quad xyx\nabla aq_2 b \vdash$$

23.



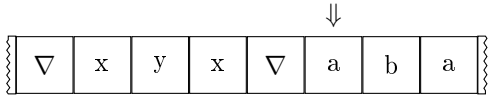
$$K_{22} \quad xyx\nabla abq_2\nabla \vdash$$

24.



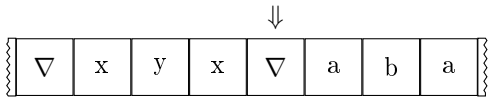
$$K_{23} \quad xyx\nabla aq_5 ba \vdash$$

25.



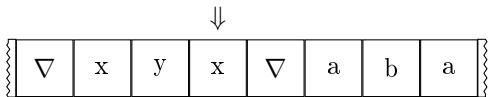
$$K_{24} \quad xyx\nabla q_5 aba \vdash$$

26.



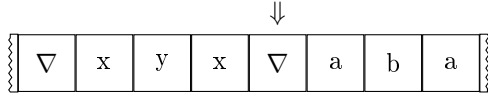
$$K_{25} \quad xyxq_5\nabla aba \vdash$$

27.



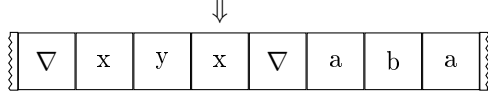
$$K_{26} \quad xyq_5x\nabla aba \vdash$$

28.



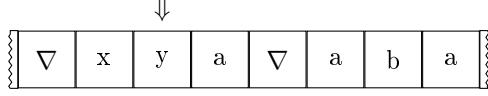
$$K_{27} \quad xyxq_0\nabla aba \vdash$$

29.



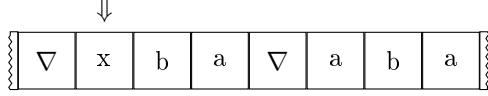
$$K_{28} \quad xyq_6x\nabla aba \vdash$$

30.



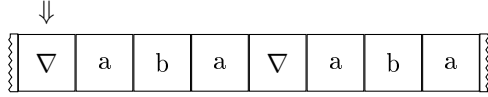
$$K_{29} \quad xq_6ya\nabla aba \vdash$$

31.



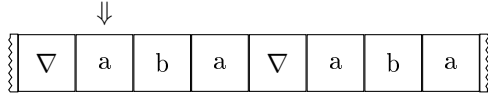
$$K_{30} \quad q_6xba\nabla aba \vdash$$

32.



$$K_{31} \quad q_6\nabla aba\nabla aba \vdash$$

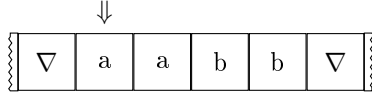
33.



$$K_{32} \quad q_7aba\nabla aba$$

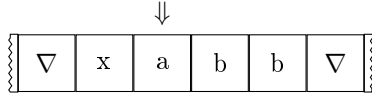
3.1.2 aabb

1.



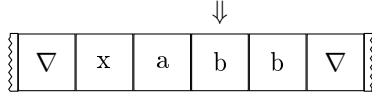
$$K_0 \quad q_0aabb \vdash$$

2.



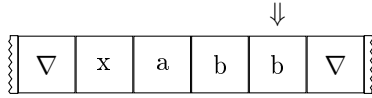
$$K_1 \quad xq_1abb \vdash$$

3.



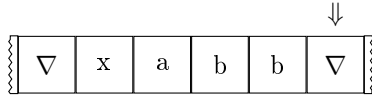
$$K_2 \quad xaq_1bb \vdash$$

4.



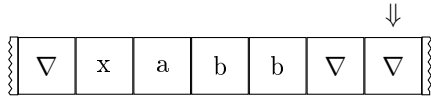
$$K_3 \quad xabq_1b \vdash$$

5.



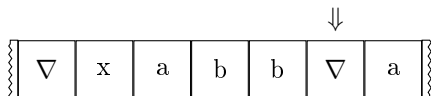
$$K_4 \quad xabbq_1\nabla \vdash$$

6.



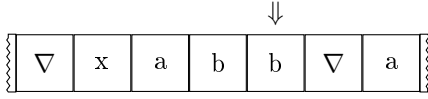
$$K_5 \quad xabb\nabla q_2\nabla \vdash$$

7.



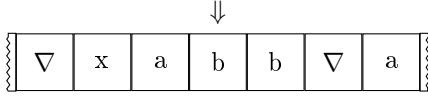
$$K_6 \quad xabbq_5\nabla a \vdash$$

8.



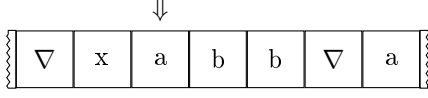
$$K_7 \quad xabq_5b\nabla a \vdash$$

9.



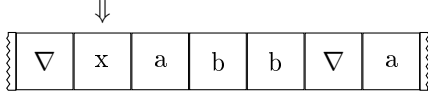
$$K_8 \quad xaq_5bb\nabla a \vdash$$

10.



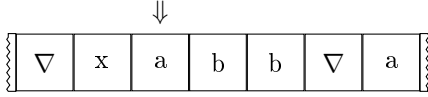
$$K_9 \quad xq_5abb\nabla a \vdash$$

11.



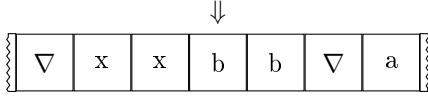
$$K_{10} \quad q_5xabb\nabla a \vdash$$

12.



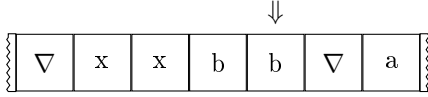
$$K_{11} \quad xq_0abb\nabla a \vdash$$

13.



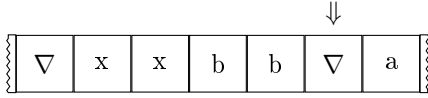
$$K_{12} \quad xxq_1bb\nabla a \vdash$$

14.



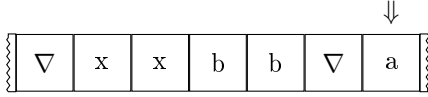
$$K_{13} \quad xxbq_1b\nabla a \vdash$$

15.



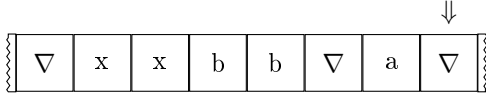
$$K_{14} \quad xxbbq_1\nabla a \vdash$$

16.



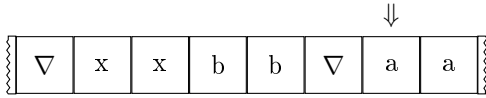
$$K_{15} \quad xxbb\nabla q_2a \vdash$$

17.



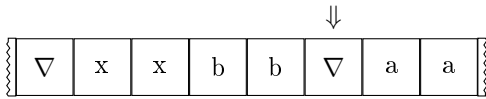
$$K_{16} \quad xxbb\nabla aq_2\nabla \vdash$$

18.



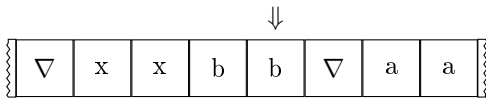
$$K_{17} \quad xxbb\nabla q_5aa \vdash$$

19.



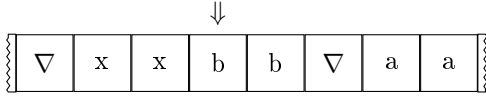
$$K_{18} \quad xxbbq_5\nabla aa \vdash$$

20.



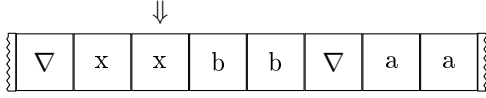
$$K_{19} \quad xxbq_5b\nabla aa \vdash$$

21.



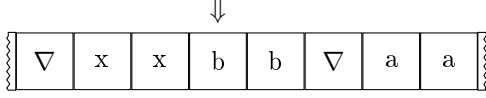
$$K_{20} \quad xxq_5bb\nabla aa \vdash$$

22.



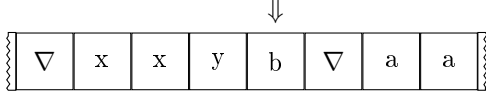
$$K_{21} \quad xq_5xb\nabla aa \vdash$$

23.



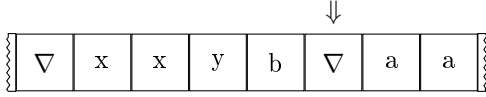
$$K_{22} \quad xxq_0bb\nabla aa \vdash$$

24.



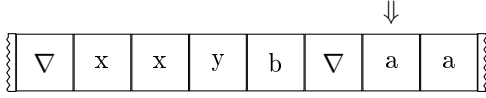
$$K_{23} \quad xxyq_3b\nabla aa \vdash$$

25.



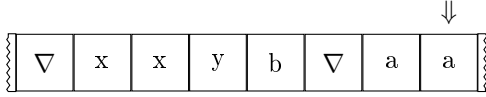
$$K_{24} \quad xxybq_3\nabla aa \vdash$$

26.



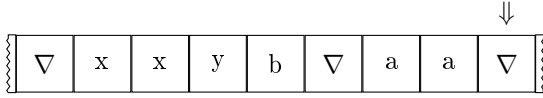
$$K_{25} \quad xxyb\nabla q_4aa \vdash$$

27.



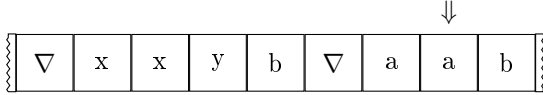
$$K_{26} \quad xxyb\nabla aq_4a \vdash$$

28.



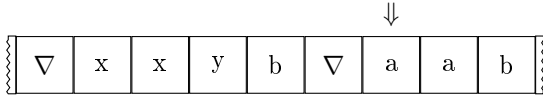
$$K_{27} \quad xxyb\nabla aaq_4\nabla \vdash$$

29.



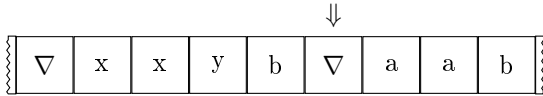
$$K_{28} \quad xxyb\nabla aq_5ab \vdash$$

30.



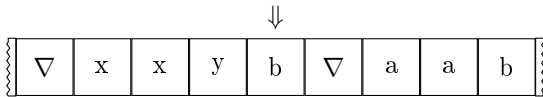
$$K_{29} \quad xxyb\nabla q_5aab \vdash$$

31.



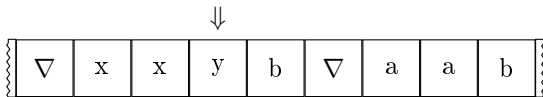
$$K_{30} \quad xxybq_5\nabla aab \vdash$$

32.



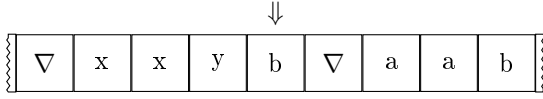
$$K_{31} \quad xxyq_5b\nabla aab \vdash$$

33.



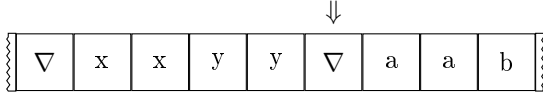
$$K_{32} \quad xxq_5yb\nabla aab \vdash$$

34.



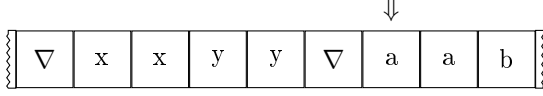
$$K_{33} \quad xxyq_0b\nabla aab \vdash$$

35.



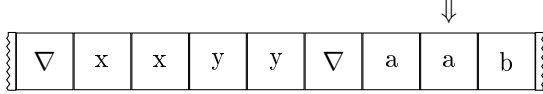
$$K_{34} \quad xxyyq_3\nabla aab \vdash$$

36.



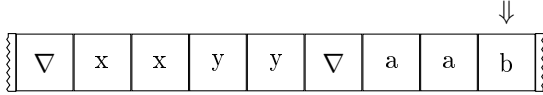
$$K_{35} \quad xxyy\nabla q_4aab \vdash$$

37.



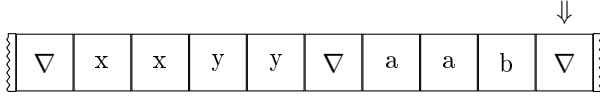
$$K_{36} \quad xxyy\nabla aq_4ab \vdash$$

38.



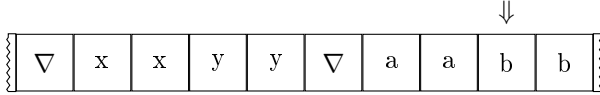
$$K_{37} \quad xxyy\nabla aaq_4b \vdash$$

39.



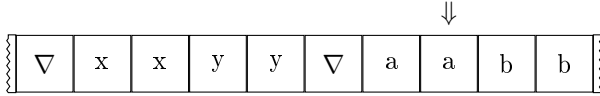
$$K_{38} \quad xxyy\nabla aabq_4\nabla \vdash$$

40.



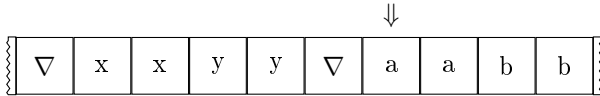
$$K_{39} \quad xxyy\nabla aaq_5bb \vdash$$

41.



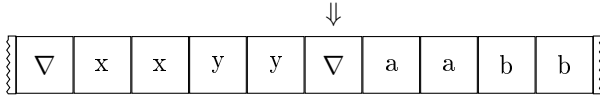
$$K_{40} \quad xxyy\nabla aq_5abb \vdash$$

42.



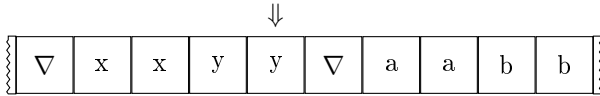
$$K_{41} \quad xxyy\nabla q_5aabb \vdash$$

43.



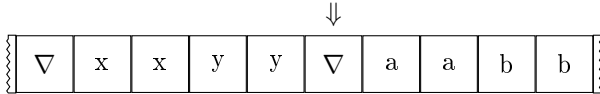
$$K_{42} \quad xxyyq_5\nabla aabb \vdash$$

44.



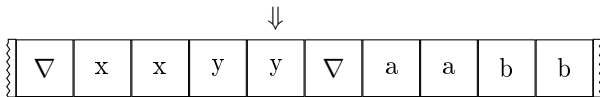
$$K_{43} \quad xxyq_5y\nabla aabb \vdash$$

45.



$$K_{44} \quad xxyyq_0\nabla aabb \vdash$$

46.



$$K_{45} \quad xxyq_6y\nabla aabb \vdash$$

47.

\Downarrow

∇	x	x	y	b	∇	a	a	b	b
----------	---	---	---	---	----------	---	---	---	---

$$K_{46} \quad \text{xx}q_6yb\nabla aabb \vdash$$

48.

\Downarrow

∇	x	x	b	b	∇	a	a	b	b
----------	---	---	---	---	----------	---	---	---	---

$$K_{47} \quad \text{x}q_6\text{xb}b\nabla aabb \vdash$$

49.

\Downarrow

∇	x	a	b	b	∇	a	a	b	b
----------	---	---	---	---	----------	---	---	---	---

$$K_{48} \quad q_6\text{xabb}\nabla aabb \vdash$$

50.

\Downarrow

∇	a	a	b	b	∇	a	a	b	b
----------	---	---	---	---	----------	---	---	---	---

$$K_{49} \quad q_6\nabla aabb\nabla aabb \vdash$$

51.

\Downarrow

∇	a	a	b	b	∇	a	a	b	b
----------	---	---	---	---	----------	---	---	---	---

$$K_{50} \quad q_7aabb\nabla aabb$$

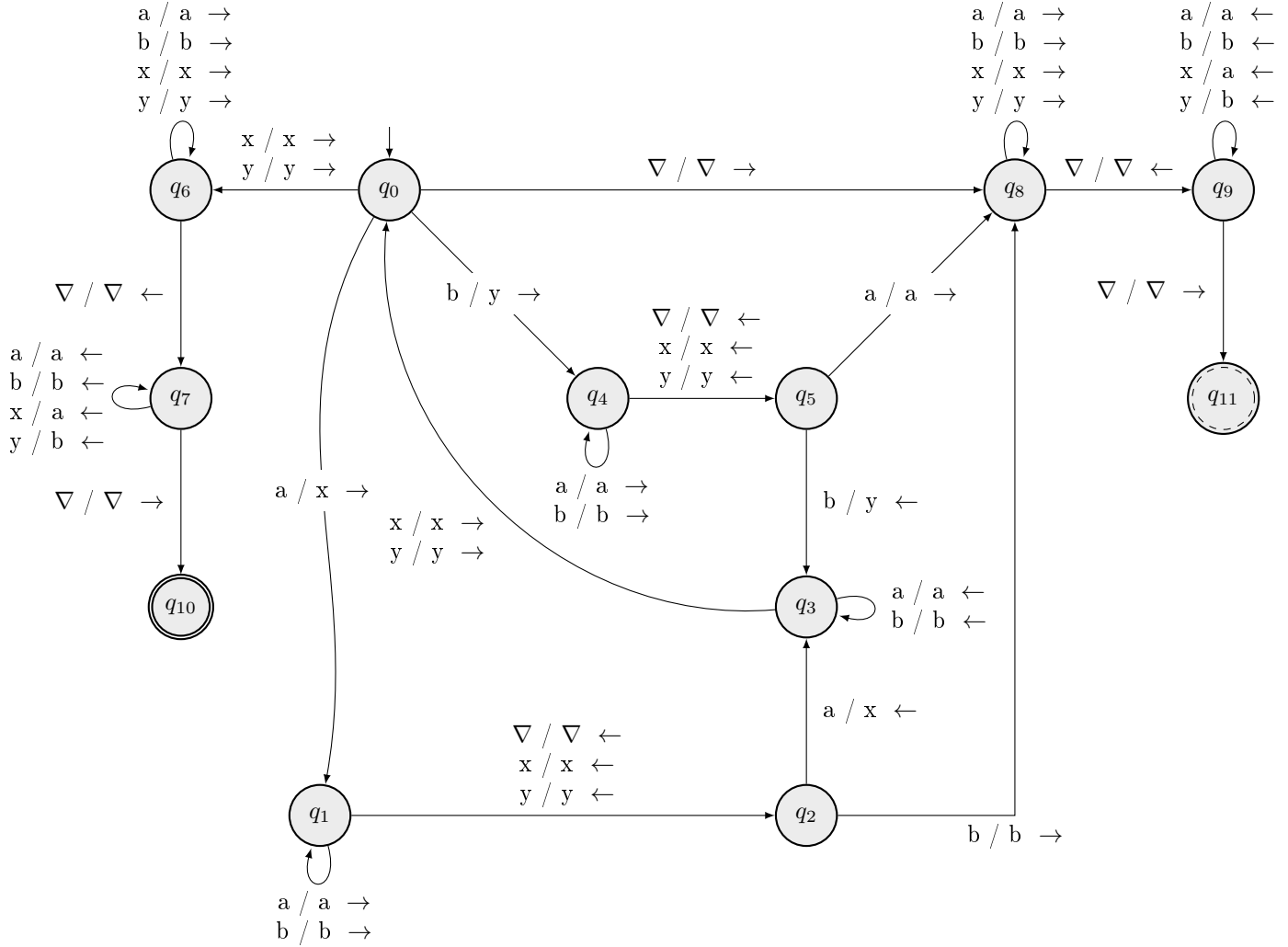
3.2 Zadanie 1.20

Zaprojektuj maszyny Turinga, która akceptuje język

$$(28) \quad L = \{\omega\omega : \omega \in \{a, b\}^+\}$$

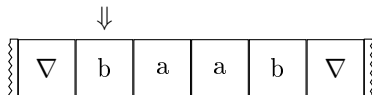
nad alfabetem $\Sigma = \{a, b\}$. Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(29) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, q_A, q_R) = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_8, q_9, q_{10}, q_{11}\}, \{a, b\}, \{a, b, x, y, \nabla\}, \delta, q_0, \{q_{10}\}, \{q_{11}\})$$



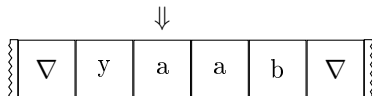
3.2.1 baab

1.



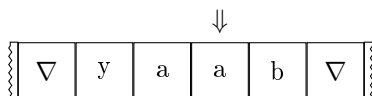
$$K_0 \quad q_0baab \vdash$$

2.



$$K_1 \quad yq_4aab \vdash$$

3.



$$K_2 \quad yaq_4ab \vdash$$

4. \Downarrow

∇	y	a	a	b	∇
----------	---	---	---	---	----------

 $K_3 \text{ yaa}q_4\text{b} \vdash$
5. \Downarrow

∇	y	a	a	b	∇
----------	---	---	---	---	----------

 $K_4 \text{ yaab}q_4\nabla \vdash$
6. \Downarrow

∇	y	a	a	b	∇
----------	---	---	---	---	----------

 $K_5 \text{ yaa}q_5\text{b} \vdash$
7. \Downarrow

∇	y	a	a	y	∇
----------	---	---	---	---	----------

 $K_6 \text{ ya}q_3\text{ay} \vdash$
8. \Downarrow

∇	y	a	a	y	∇
----------	---	---	---	---	----------

 $K_7 \text{ y}q_3\text{aay} \vdash$
9. \Downarrow

∇	y	a	a	y	∇
----------	---	---	---	---	----------

 $K_8 \text{ }q_3\text{yaay} \vdash$
10. \Downarrow

∇	y	a	a	y	∇
----------	---	---	---	---	----------

 $K_9 \text{ y}q_0\text{aay} \vdash$
11. \Downarrow

∇	y	x	a	y	∇
----------	---	---	---	---	----------

 $K_{10} \text{ yx}q_1\text{ay} \vdash$
12. \Downarrow

∇	y	x	a	y	∇
----------	---	---	---	---	----------

 $K_{11} \text{ yxa}q_1\text{y} \vdash$
13. \Downarrow

∇	y	x	a	y	∇
----------	---	---	---	---	----------

 $K_{12} \text{ yx}q_2\text{ay} \vdash$
14. \Downarrow

∇	y	x	x	y	∇
----------	---	---	---	---	----------

 $K_{13} \text{ y}q_3\text{xx}y \vdash$
15. \Downarrow

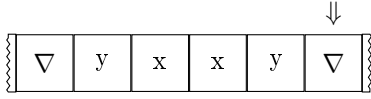
∇	y	x	x	y	∇
----------	---	---	---	---	----------

 $K_{14} \text{ yx}q_0\text{xy} \vdash$
16. \Downarrow

∇	y	x	x	y	∇
----------	---	---	---	---	----------

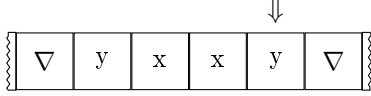
 $K_{15} \text{ yxx}q_6\text{y} \vdash$

17.



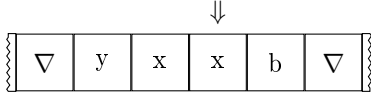
$$K_{16} \quad yxx y q_6 \nabla \vdash$$

18.



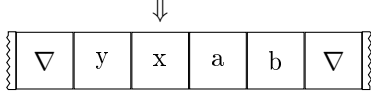
$$K_{17} \quad yxx q_7 y \vdash$$

19.



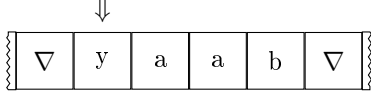
$$K_{18} \quad yx q_7 x b \vdash$$

20.



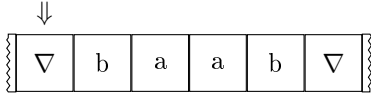
$$K_{19} \quad y q_7 x a b \vdash$$

21.



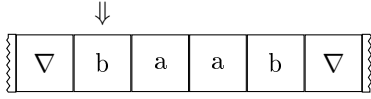
$$K_{20} \quad q_7 y a a b \vdash$$

22.



$$K_{21} \quad q_7 \nabla b a a b \vdash$$

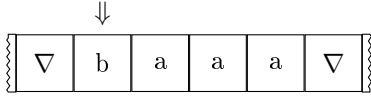
23.



$$K_{22} \quad q_{10} b a a b$$

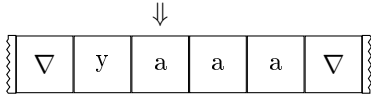
3.2.2 baaa

1.



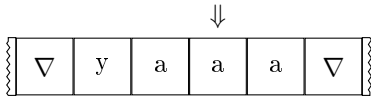
$$K_0 \quad q_0 b a a a \vdash$$

2.



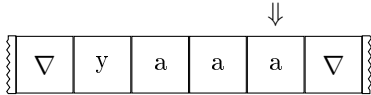
$$K_1 \quad y q_4 a a a \vdash$$

3.



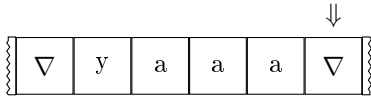
$$K_2 \quad y a q_4 a a \vdash$$

4.



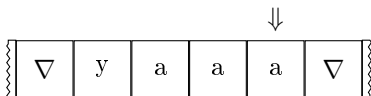
$$K_3 \quad y a a q_4 a \vdash$$

5.



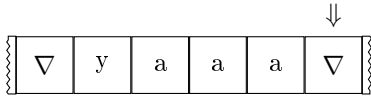
$$K_4 \quad y a a a q_4 \nabla \vdash$$

6.



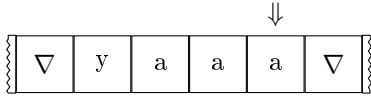
$$K_5 \quad y a a q_5 a \vdash$$

7.



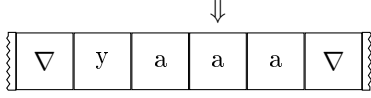
$$K_6 \quad yaaaq_8 \nabla \vdash$$

8.



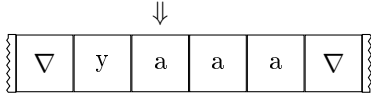
$$K_7 \quad yaaq_9 a \vdash$$

9.



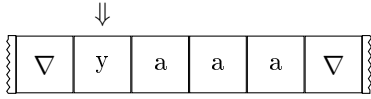
$$K_8 \quad yaq_8 aa \vdash$$

10.



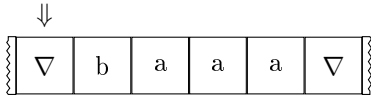
$$K_9 \quad yq_9 aaa \vdash$$

11.



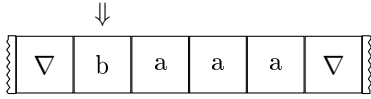
$$K_{10} \quad q_9 yaaa \vdash$$

12.



$$K_{11} \quad q_9 \nabla baaa \vdash$$

13.



$$K_{12} \quad q_{11} baaa$$

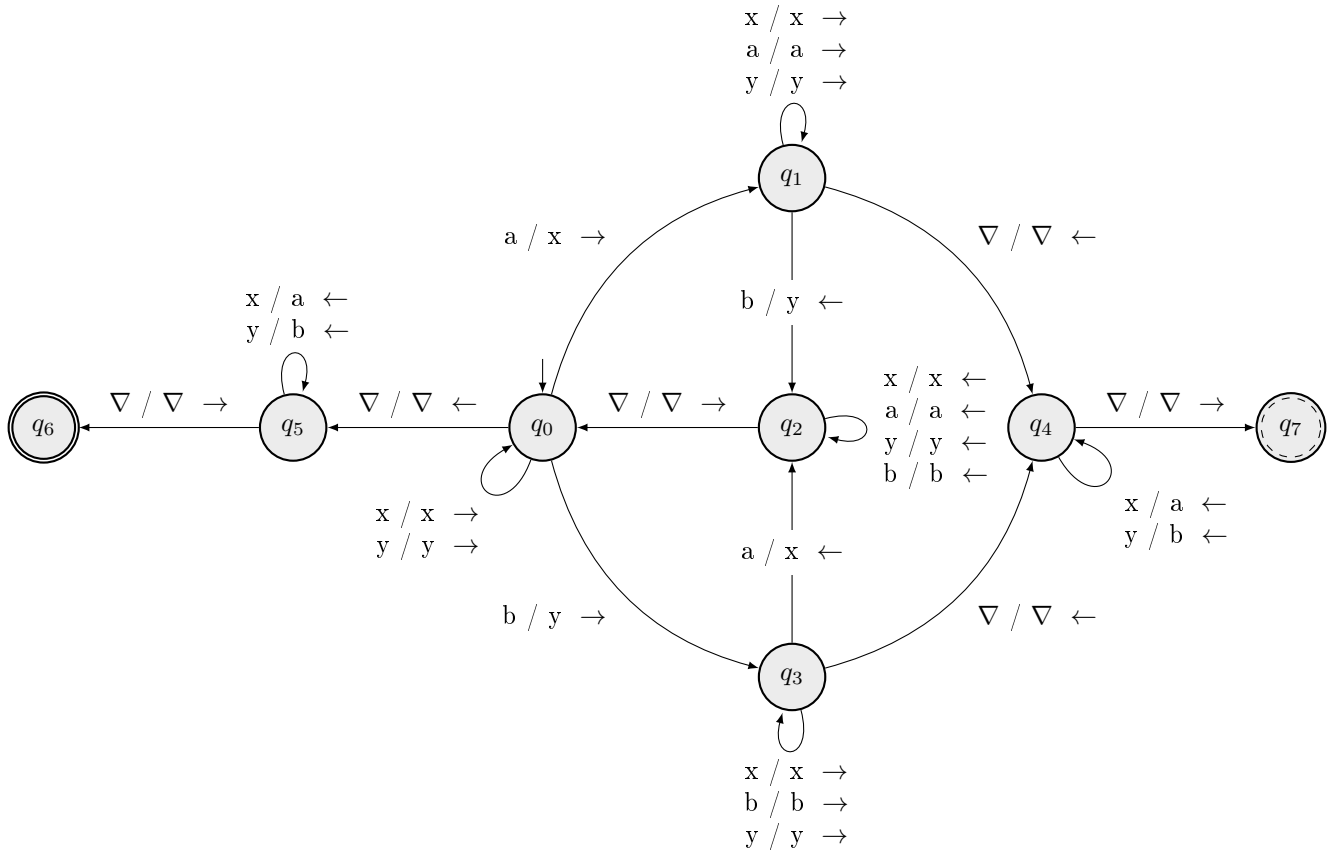
3.3 Zadanie 1.22

Zaprojektuj maszynę Turinga nad alfabetem $\Sigma = \{a, b\}$, która akceptuje język

$$(30) \quad L = \{\omega : \omega \text{ zawiera równą liczbę symboli } a \text{ i } b\}$$

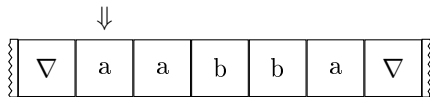
Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(31) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, q_A, q_R) = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6, q_7\}, \{a, b\}, \{a, b, x, y, \nabla\}, \delta, q_0, \{q_6\}, \{q_7\})$$



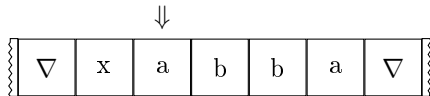
3.3.1 aabba

1.



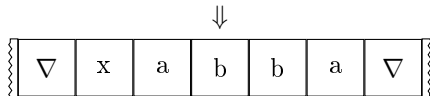
$$K_0 \quad q_0 aabba \vdash$$

2.



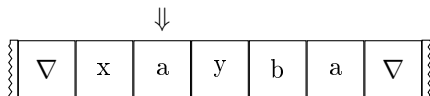
$$K_1 \quad xq_1 abba \vdash$$

3.



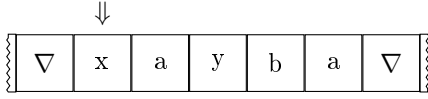
$$K_2 \quad xaq_1 bba \vdash$$

4.



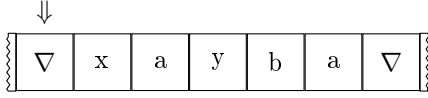
$$K_3 \quad xq_2 ayba \vdash$$

5.



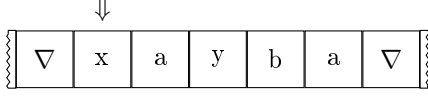
$$K_4 \quad q_2 x a y b a \vdash$$

6.



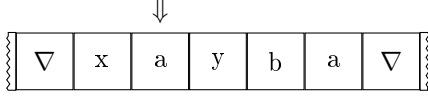
$$K_5 \quad q_2 \nabla x a y b a \vdash$$

7.



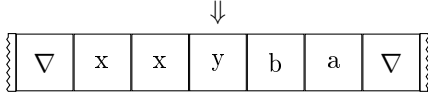
$$K_6 \quad q_0 x a y b a \vdash$$

8.



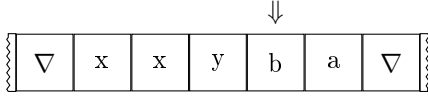
$$K_7 \quad x q_0 a y b a \vdash$$

9.



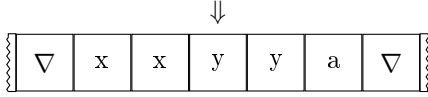
$$K_8 \quad x x q_1 y b a \vdash$$

10.



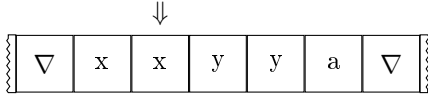
$$K_9 \quad x x y q_1 b a \vdash$$

11.



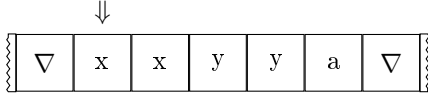
$$K_{10} \quad x x q_2 y y a \vdash$$

12.



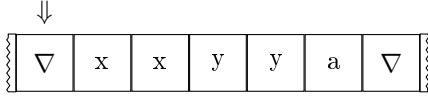
$$K_{11} \quad x q_2 x y y a \vdash$$

13.



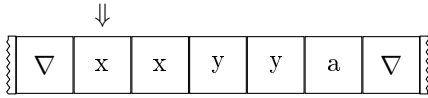
$$K_{12} \quad q_2 x x y y a \vdash$$

14.



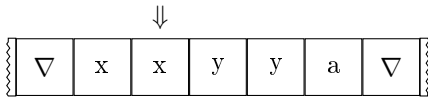
$$K_{13} \quad q_2 \nabla x x y y a \vdash$$

15.



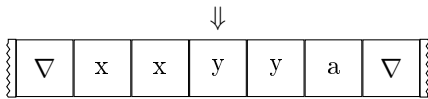
$$K_{14} \quad q_0 x x y y a \vdash$$

16.



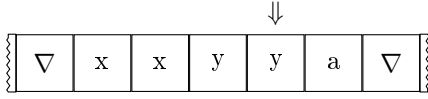
$$K_{15} \quad x q_0 x y y a \vdash$$

17.



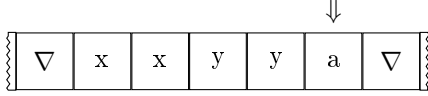
$$K_{16} \quad x x q_0 y y a \vdash$$

18.



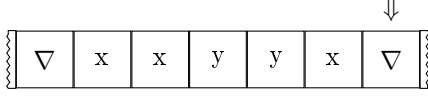
$K_{17} \quad xxyq_0ya \vdash$

19.



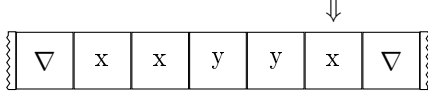
$K_{18} \quad xxyyq_0a \vdash$

20.



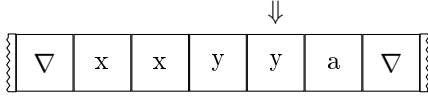
$K_{19} \quad xxyyxq_1\nabla \vdash$

21.



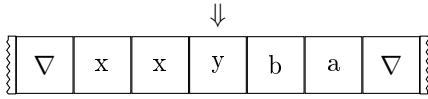
$K_{20} \quad xxyyq_4x \vdash$

22.



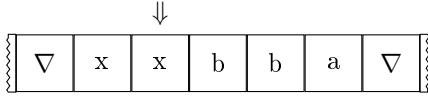
$K_{21} \quad xxyq_4ya \vdash$

23.



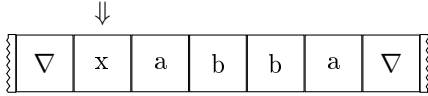
$K_{22} \quad xxq_4yba \vdash$

24.



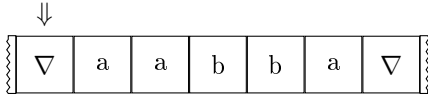
$K_{23} \quad xq_4xbba \vdash$

25.



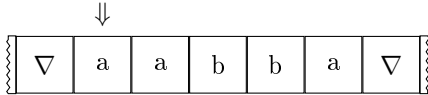
$K_{24} \quad q_4xabba \vdash$

26.



$K_{25} \quad q_4\nabla aabba \vdash$

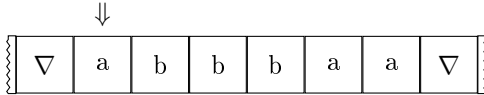
27.



$K_{26} \quad q_7aabba$

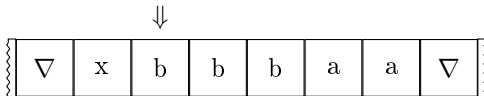
3.3.2 abbbaa

1.



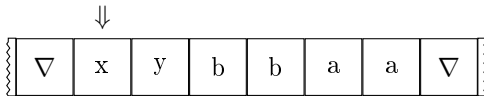
$K_0 \quad q_0abbbaa \vdash$

2.



$K_1 \quad xq_1bbbaa \vdash$

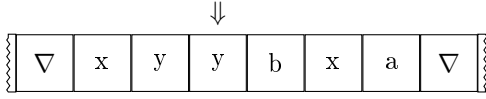
3.



$K_2 \quad q_2xybbaa \vdash$

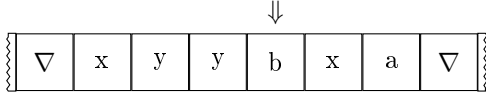
4. \Downarrow
- | | | | | | | | |
|----------|---|---|---|---|---|---|----------|
| ∇ | x | y | b | b | a | a | ∇ |
|----------|---|---|---|---|---|---|----------|
- $K_3 \quad q_2 \nabla x y b b a a \vdash$
5. \Downarrow
- | | | | | | | | |
|----------|---|---|---|---|---|---|----------|
| ∇ | x | y | b | b | a | a | ∇ |
|----------|---|---|---|---|---|---|----------|
- $K_4 \quad q_0 x y b b a a \vdash$
6. \Downarrow
- | | | | | | | | |
|----------|---|---|---|---|---|---|----------|
| ∇ | x | y | b | b | a | a | ∇ |
|----------|---|---|---|---|---|---|----------|
- $K_5 \quad x q_0 y b b a a \vdash$
7. \Downarrow
- | | | | | | | | |
|----------|---|---|---|---|---|---|----------|
| ∇ | x | y | b | b | a | a | ∇ |
|----------|---|---|---|---|---|---|----------|
- $K_6 \quad x y q_0 b b a a \vdash$
8. \Downarrow
- | | | | | | | | |
|----------|---|---|---|---|---|---|----------|
| ∇ | x | y | y | b | a | a | ∇ |
|----------|---|---|---|---|---|---|----------|
- $K_7 \quad x y y q_3 b a a \vdash$
9. \Downarrow
- | | | | | | | | |
|----------|---|---|---|---|---|---|----------|
| ∇ | x | y | y | b | a | a | ∇ |
|----------|---|---|---|---|---|---|----------|
- $K_8 \quad x y y b q_3 a a \vdash$
10. \Downarrow
- | | | | | | | | |
|----------|---|---|---|---|---|---|----------|
| ∇ | x | y | y | b | x | a | ∇ |
|----------|---|---|---|---|---|---|----------|
- $K_9 \quad x y y q_2 b x a \vdash$
11. \Downarrow
- | | | | | | | | |
|----------|---|---|---|---|---|---|----------|
| ∇ | x | y | y | b | x | a | ∇ |
|----------|---|---|---|---|---|---|----------|
- $K_{10} \quad x y q_2 y b x a \vdash$
12. \Downarrow
- | | | | | | | | |
|----------|---|---|---|---|---|---|----------|
| ∇ | x | y | y | b | x | a | ∇ |
|----------|---|---|---|---|---|---|----------|
- $K_{11} \quad x q_2 y y b x a \vdash$
13. \Downarrow
- | | | | | | | | |
|----------|---|---|---|---|---|---|----------|
| ∇ | x | y | y | b | x | a | ∇ |
|----------|---|---|---|---|---|---|----------|
- $K_{12} \quad q_2 x y y b x a \vdash$
14. \Downarrow
- | | | | | | | | |
|----------|---|---|---|---|---|---|----------|
| ∇ | x | y | y | b | x | a | ∇ |
|----------|---|---|---|---|---|---|----------|
- $K_{13} \quad q_2 \nabla x y y b x a \vdash$
15. \Downarrow
- | | | | | | | | |
|----------|---|---|---|---|---|---|----------|
| ∇ | x | y | y | b | x | a | ∇ |
|----------|---|---|---|---|---|---|----------|
- $K_{14} \quad q_0 x y y b x a \vdash$
16. \Downarrow
- | | | | | | | | |
|----------|---|---|---|---|---|---|----------|
| ∇ | x | y | y | b | x | a | ∇ |
|----------|---|---|---|---|---|---|----------|
- $K_{15} \quad x q_0 y y b x a \vdash$

17.



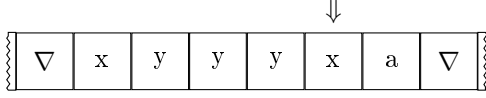
$K_{16} \quad xyq_0ybx a \vdash$

18.



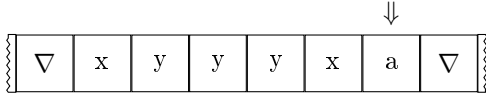
$K_{17} \quad xyyq_0bxa \vdash$

19.



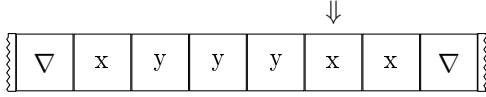
$K_{18} \quad xyyyq_3xa \vdash$

20.



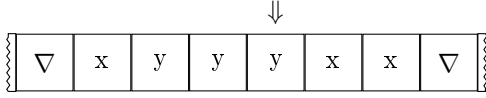
$K_{19} \quad xyyyxq_3a \vdash$

21.



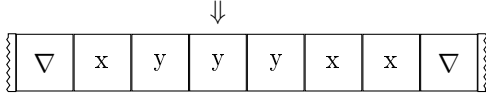
$K_{20} \quad xyyyq_2xx \vdash$

22.



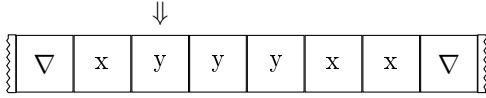
$K_{21} \quad xyyq_2yxx \vdash$

23.



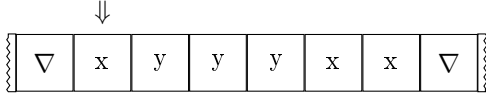
$K_{22} \quad xyq_2yyxx \vdash$

24.



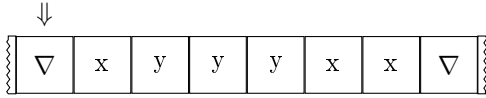
$K_{23} \quad xq_2yyyxx \vdash$

25.



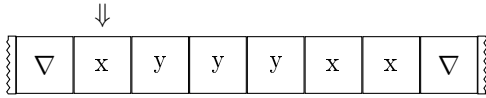
$K_{24} \quad q_2xyyyxx \vdash$

26.



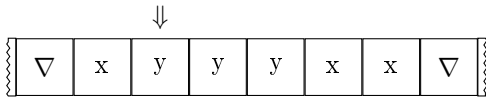
$K_{25} \quad q_2\nabla xyyyxx \vdash$

27.



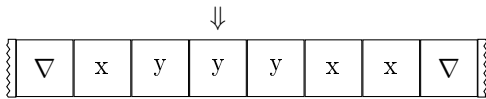
$K_{26} \quad q_0xyyyxx \vdash$

28.



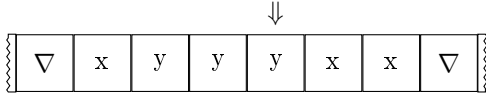
$K_{27} \quad xq_0yyyxx \vdash$

29.



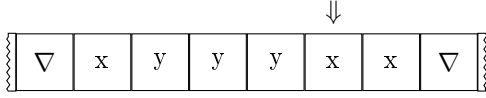
$K_{28} \quad xyq_0yyxx \vdash$

30.



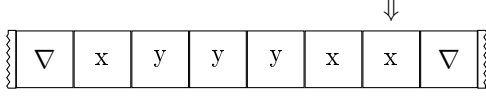
$$K_{29} \quad xyyq_0yxx \vdash$$

31.



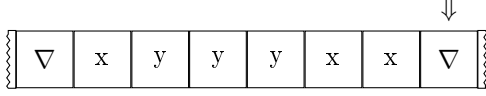
$$K_{30} \quad xy yy q_0 xx \vdash$$

32.



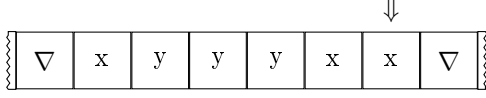
$$K_{31} \quad xy yy x q_0 x \vdash$$

33.



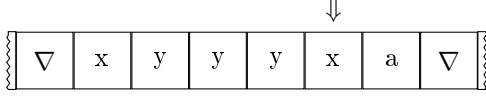
$$K_{32} \quad xy yy xx q_0 \nabla \vdash$$

34.



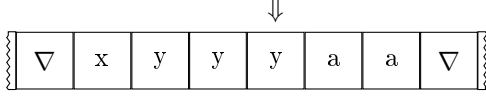
$$K_{33} \quad xy yy x q_5 x \vdash$$

35.



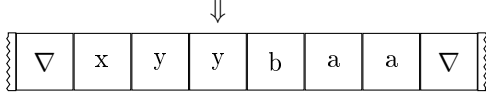
$$K_{34} \quad xy yy q_5 xa \vdash$$

36.



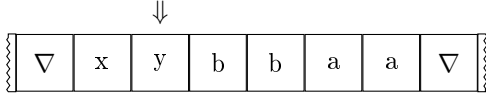
$$K_{35} \quad xy y q_5 yaa \vdash$$

37.



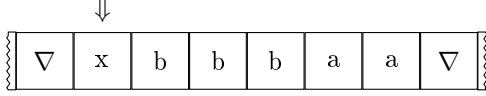
$$K_{36} \quad xy q_5 ybaa \vdash$$

38.



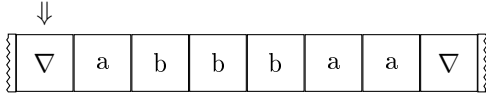
$$K_{37} \quad x q_5 ybbaa \vdash$$

39.



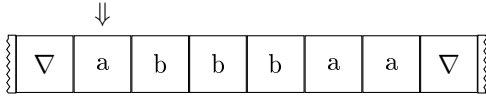
$$K_{38} \quad q_5 xbbbaa \vdash$$

40.



$$K_{39} \quad q_5 \nabla abbbaa \vdash$$

41.



$$K_{40} \quad q_6 abbbaa$$

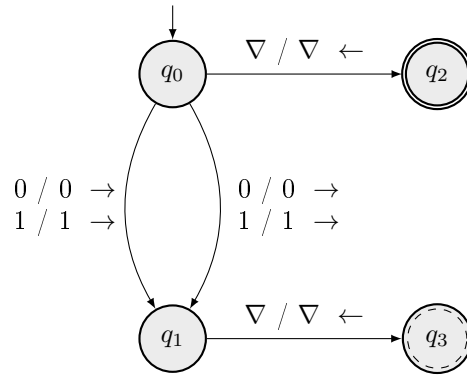
3.4 Zadanie 1.23

Zaprojektuj maszynę Turinga, która akceptuje język

$$(32) \quad L = \{\omega : |\omega| \text{ jest parzysta}\}$$

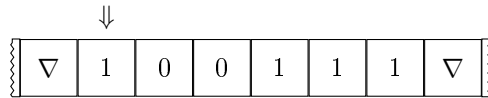
nad alfabetem $\Sigma = \{0, 1\}$. Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(33) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, q_A, q_R) = (\{q_0, q_1, q_2, q_3\}, \{0, 1\}, \{0, 1, \nabla\}, \delta, q_0, \{q_2\}, \{q_3\})$$



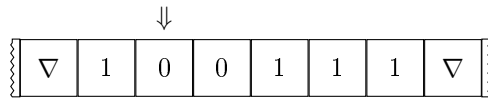
3.4.1 100111

1.



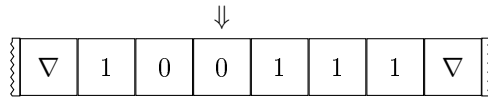
$K_0 \quad q_0 100111 \vdash$

2.



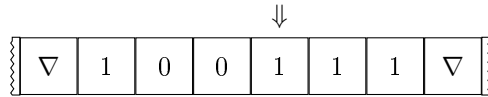
$K_1 \quad 1q_1 00111 \vdash$

3.



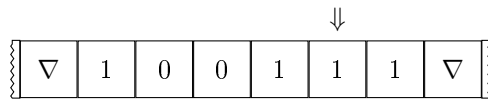
$K_2 \quad 10q_0 0111 \vdash$

4.



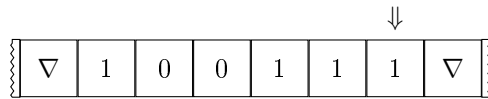
$K_3 \quad 100q_1 111 \vdash$

5.



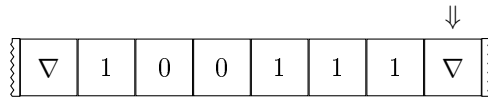
$K_4 \quad 1001q_0 11 \vdash$

6.



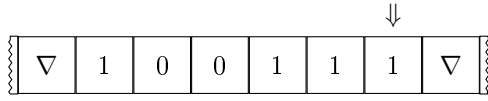
$K_5 \quad 10011q_1 1 \vdash$

7.



$K_6 \quad 100111q_0 \nabla \vdash$

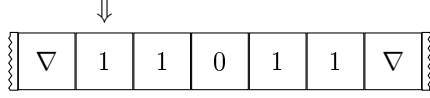
8.



$K_7 \quad 10011q_21$

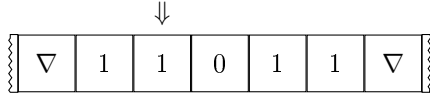
3.4.2 11011

1.



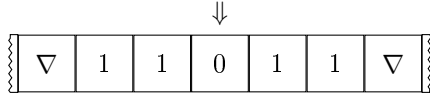
$K_0 \quad q_011011 \vdash$

2.



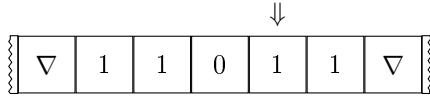
$K_1 \quad 1q_11011 \vdash$

3.



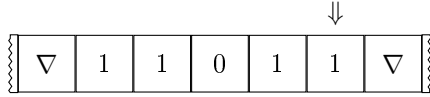
$K_2 \quad 11q_0011 \vdash$

4.



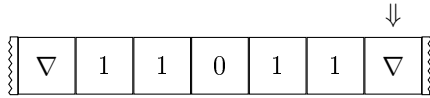
$K_3 \quad 110q_111 \vdash$

5.



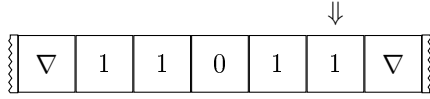
$K_4 \quad 1101q_01 \vdash$

6.



$K_5 \quad 11011q_1\nabla \vdash$

7.



$K_6 \quad 1101q_31$

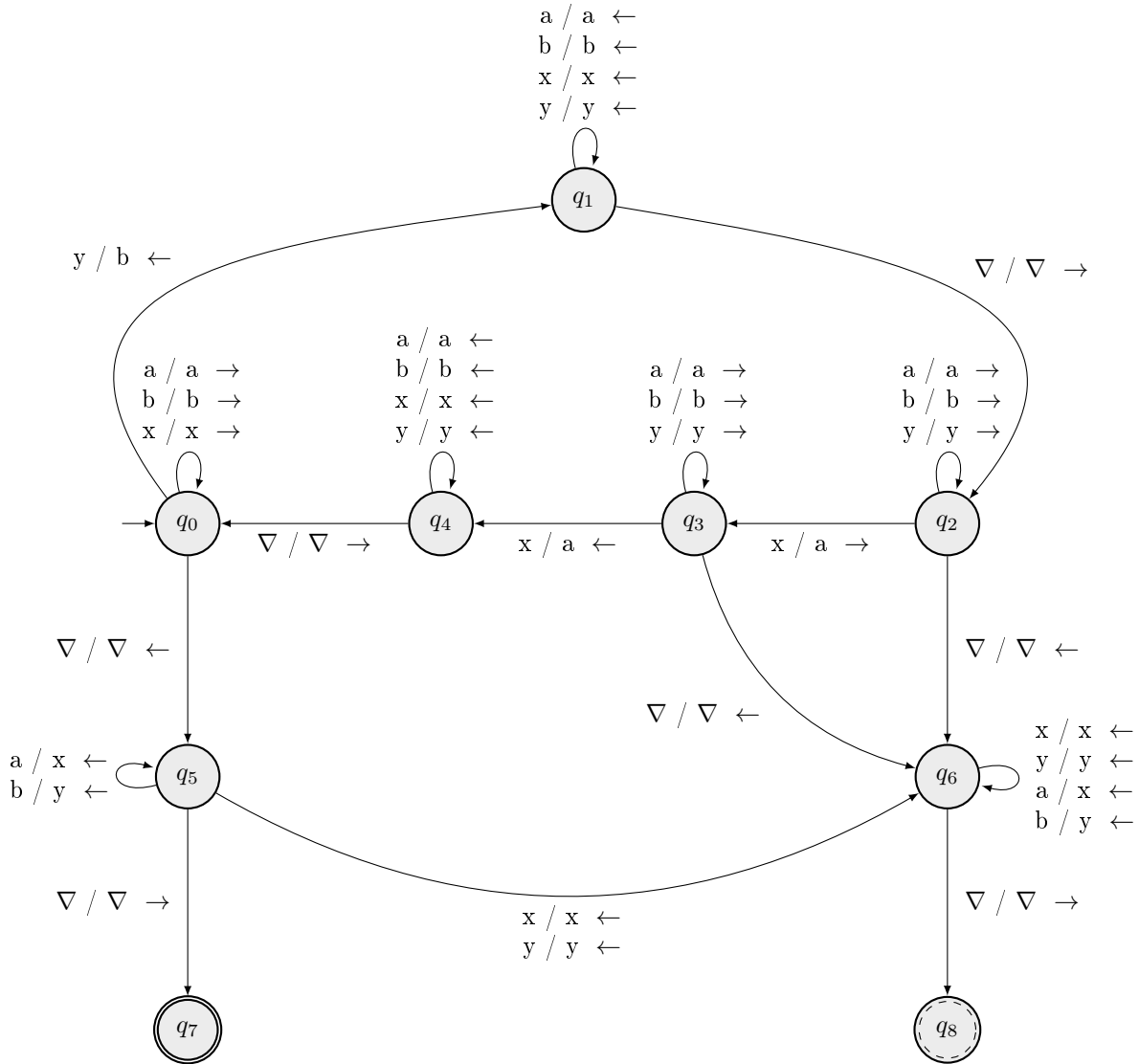
3.5 Zadanie 1.24

Zaprojektuj maszynę Turinga nad alfabetem $\Sigma = \{x, y\}$, która akceptuje język

(34) Maszyna Turinga akceptująca język $L = \{\omega : |\omega| \text{ ma dwa razy więcej symboli } x \text{ niż } y\}$

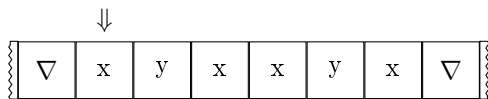
Narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

(35) $M = (Q, \Sigma, \Gamma, \delta, q_0, q_A, q_R) = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_8\}, \{x, y\}, \{x, y, a, b, \nabla\}, \delta, q_0, \{q_7\}, \{q_8\})$



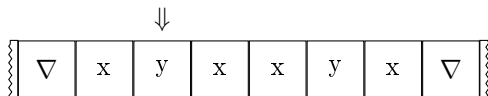
3.5.1 xyxxxyx

1.



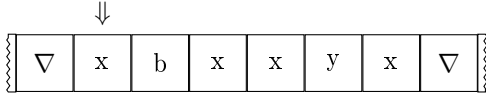
$K_0 \quad q_0xyxxxyx \vdash$

2.



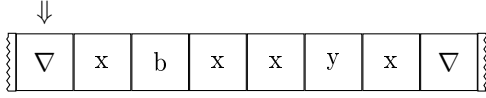
$K_1 \quad xq_0yxxxyx \vdash$

3.



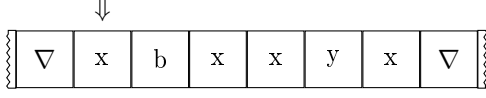
$K_2 \quad q_1 x b x x y x \vdash$

4.



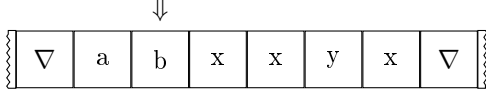
$K_3 \quad q_1 \nabla x b x x y x \vdash$

5.



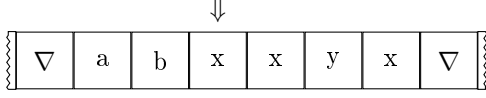
$K_4 \quad q_2 x b x x y x \vdash$

6.



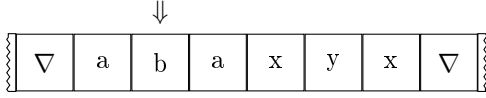
$K_5 \quad a q_3 b x x y x \vdash$

7.



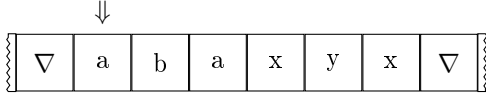
$K_6 \quad a b q_3 x x y x \vdash$

8.



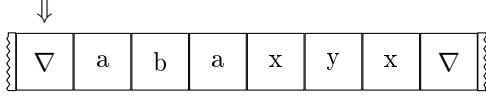
$K_7 \quad a q_4 b a x y x \vdash$

9.



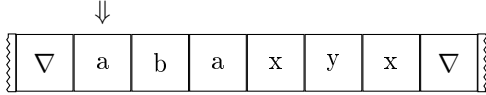
$K_8 \quad q_4 a b a x y x \vdash$

10.



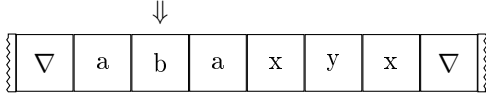
$K_9 \quad q_4 \nabla a b a x y x \vdash$

11.



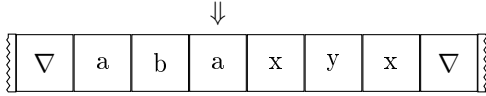
$K_{10} \quad q_0 a b a x y x \vdash$

12.



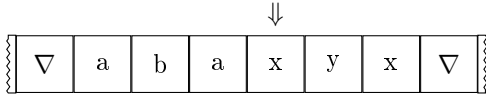
$K_{11} \quad a q_0 b a x y x \vdash$

13.



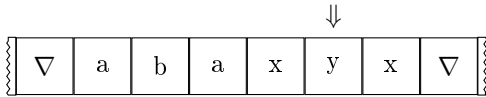
$K_{12} \quad a b q_0 a x y x \vdash$

14.



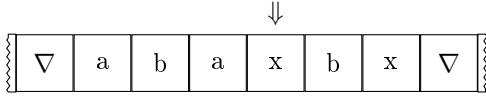
$K_{13} \quad a b a q_0 x y x \vdash$

15.

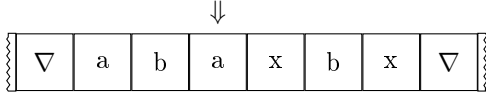


$K_{14} \quad a b a x q_0 y x \vdash$

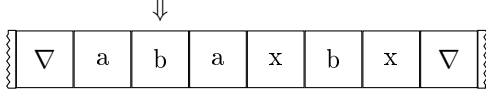
16.

 $K_{15} \quad abaq_1xbx \vdash$

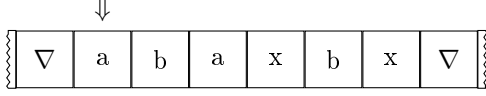
17.

 $K_{16} \quad abq_1axbx \vdash$

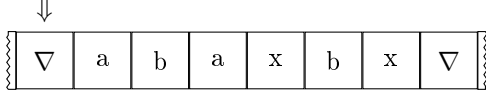
18.

 $K_{17} \quad aq_1baxbx \vdash$

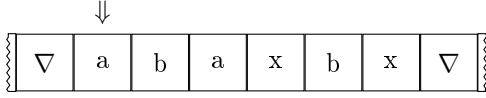
19.

 $K_{18} \quad q_1abaxbx \vdash$

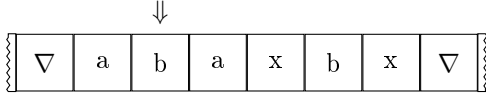
20.

 $K_{19} \quad q_1\nabla abaxbx \vdash$

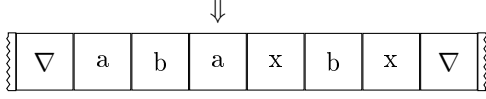
21.

 $K_{20} \quad q_2abaxbx \vdash$

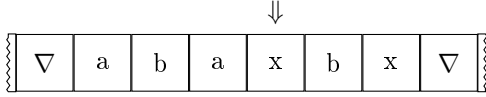
22.

 $K_{21} \quad aq_2baxbx \vdash$

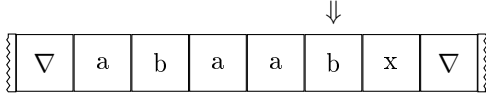
23.

 $K_{22} \quad abq_2axbx \vdash$

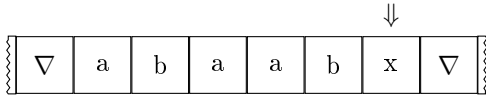
24.

 $K_{23} \quad abaq_2xbx \vdash$

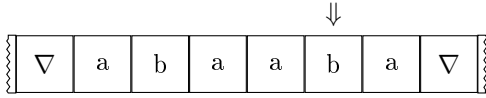
25.

 $K_{24} \quad abaaq_3bx \vdash$

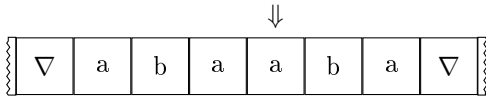
26.

 $K_{25} \quad abaabq_3x \vdash$

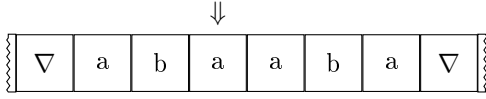
27.

 $K_{26} \quad abaaq_4ba \vdash$

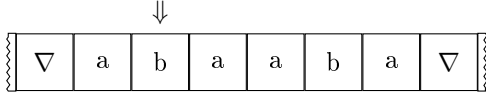
28.

 $K_{27} \quad abaq_4aba \vdash$

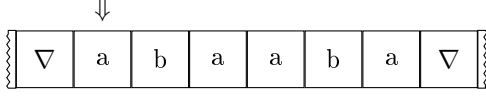
29.

 $K_{28} \quad abq_4aaba \vdash$

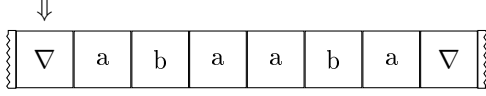
30.

 $K_{29} \quad aq_4baaba \vdash$

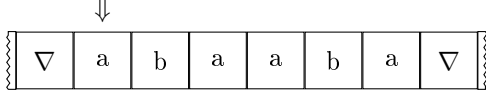
31.

 $K_{30} \quad q_4abaaba \vdash$

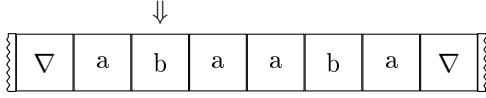
32.

 $K_{31} \quad q_4\nabla abaaba \vdash$

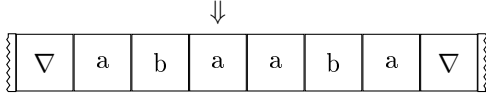
33.

 $K_{32} \quad q_0abaaba \vdash$

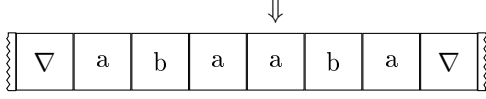
34.

 $K_{33} \quad aq_0baaba \vdash$

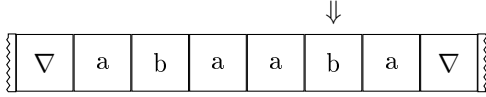
35.

 $K_{34} \quad abq_0aaba \vdash$

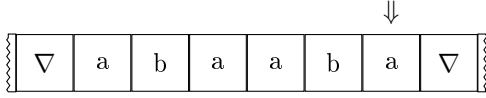
36.

 $K_{35} \quad abaq_0aba \vdash$

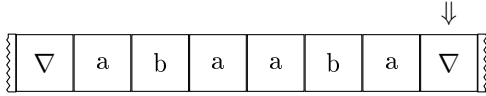
37.

 $K_{36} \quad abaaq_0ba \vdash$

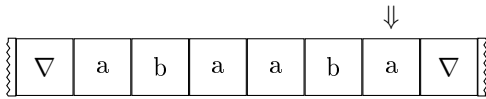
38.

 $K_{37} \quad abaabq_0a \vdash$

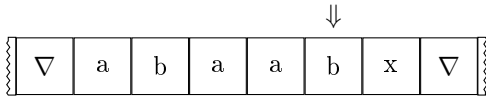
39.

 $K_{38} \quad abaabaq_0\nabla \vdash$

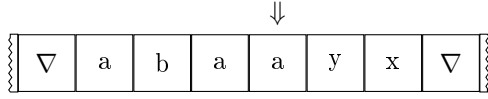
40.

 $K_{39} \quad abaabq_5a \vdash$

41.

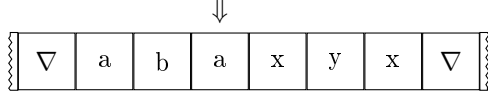
 $K_{40} \quad abaaq_5bx \vdash$

42.



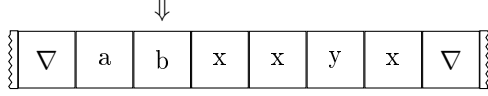
$$K_{41} \quad \text{aba}q_5\text{ayx} \vdash$$

43.



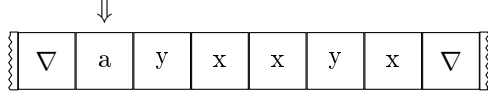
$$K_{42} \quad \text{ab}q_5\text{axyx} \vdash$$

44.



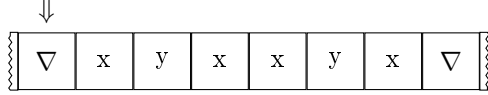
$$K_{43} \quad \text{a}q_5\text{bxxyx} \vdash$$

45.



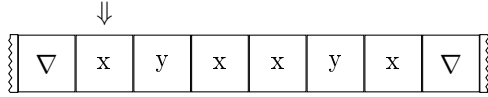
$$K_{44} \quad q_5\text{ayxxyx} \vdash$$

46.



$$K_{45} \quad q_5\nabla\text{xyxxyx} \vdash$$

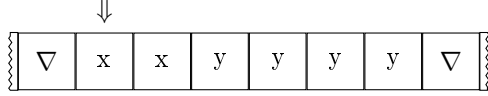
47.



$$K_{46} \quad q_7\text{xyxxyx}$$

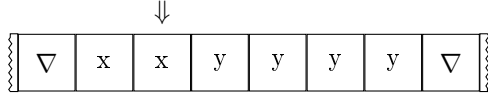
3.5.2 xxyyyy

1.



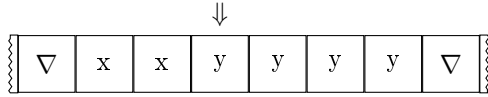
$$K_0 \quad q_0\text{xyyyy} \vdash$$

2.



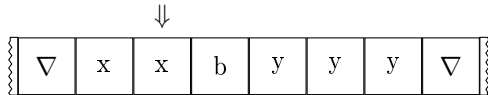
$$K_1 \quad \text{x}q_0\text{xyyyy} \vdash$$

3.



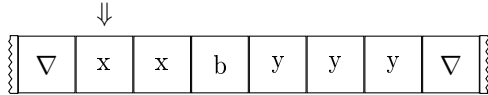
$$K_2 \quad \text{xx}q_0\text{yyyy} \vdash$$

4.



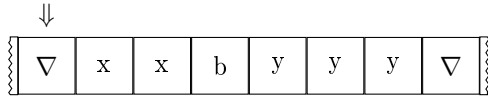
$$K_3 \quad \text{x}q_1\text{byyy} \vdash$$

5.



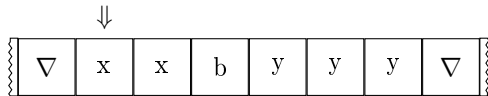
$$K_4 \quad q_1\text{xxbyyy} \vdash$$

6.



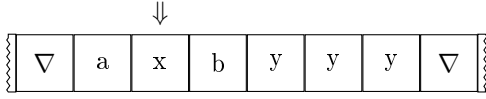
$$K_5 \quad q_1\nabla\text{xxbyyy} \vdash$$

7.



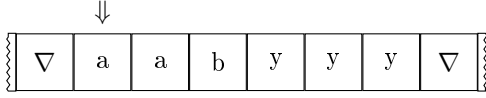
$$K_6 \quad q_2\text{xxbyyy} \vdash$$

8.



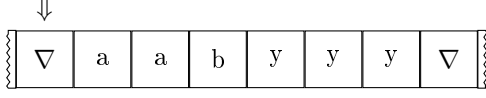
$K_7 \quad aq_3xbyyy \vdash$

9.



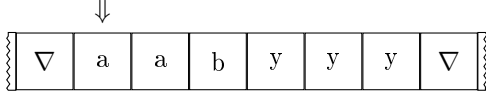
$K_8 \quad q_4aabyyy \vdash$

10.



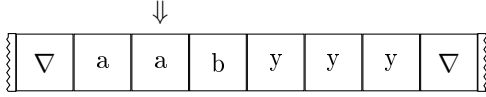
$K_9 \quad q_4\nabla aabyyy \vdash$

11.



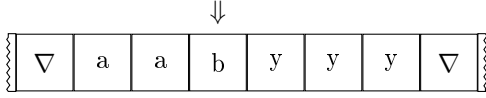
$K_{10} \quad q_0aabyyy \vdash$

12.



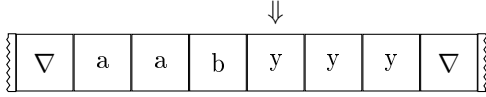
$K_{11} \quad aq_0abyyy \vdash$

13.



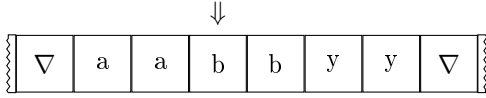
$K_{12} \quad aaq_0byyy \vdash$

14.



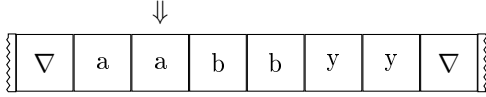
$K_{13} \quad aabq_0yyy \vdash$

15.



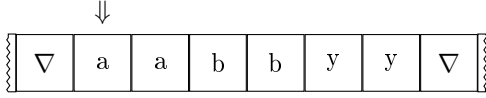
$K_{14} \quad aaq_1bbyy \vdash$

16.



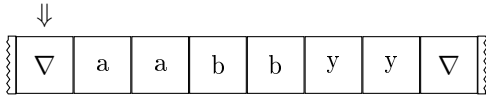
$K_{15} \quad aq_1abbyy \vdash$

17.



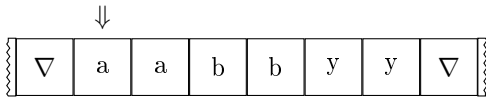
$K_{16} \quad q_1aabbyy \vdash$

18.



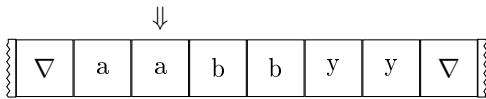
$K_{17} \quad q_1\nabla aabbyy \vdash$

19.



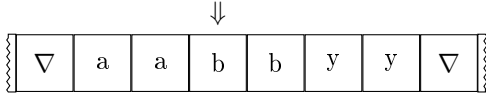
$K_{18} \quad q_2aabbyy \vdash$

20.

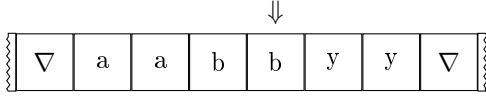


$K_{19} \quad aq_2abbyy \vdash$

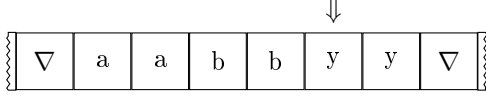
21.

 $K_{20} \quad aaq_2bbyy \vdash$

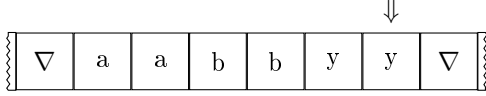
22.

 $K_{21} \quad aabq_2byy \vdash$

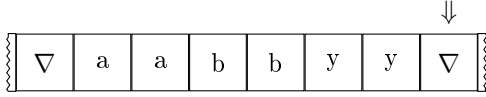
23.

 $K_{22} \quad aabbq_2yy \vdash$

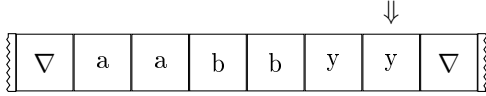
24.

 $K_{23} \quad aabbyq_2y \vdash$

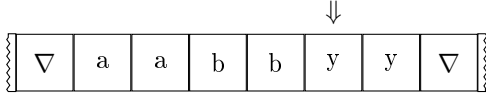
25.

 $K_{24} \quad aabbyyq_2\nabla \vdash$

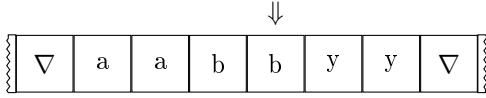
26.

 $K_{25} \quad aabbyq_6y \vdash$

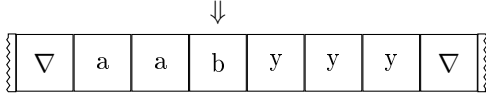
27.

 $K_{26} \quad aabbq_6yy \vdash$

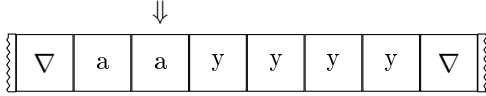
28.

 $K_{27} \quad aabq_6byy \vdash$

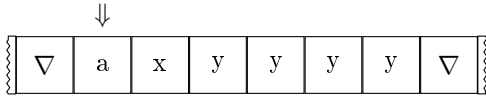
29.

 $K_{28} \quad aaq_6byyy \vdash$

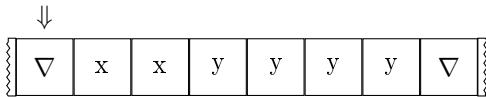
30.

 $K_{29} \quad aq_6ayyyy \vdash$

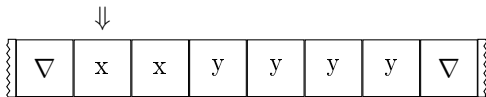
31.

 $K_{30} \quad q_6axyyyy \vdash$

32.

 $K_{31} \quad q_6\nabla xxyyyy \vdash$

33.

 $K_{32} \quad q_8xxyyyy$

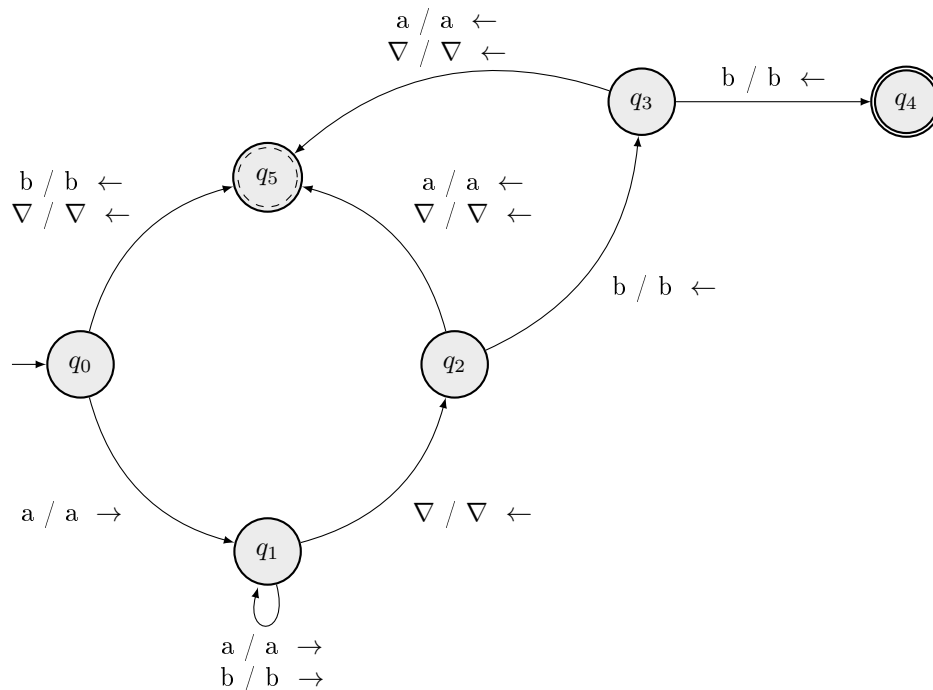
4 Maszyny Turinga i wyrażenia regularne

4.1 Zadanie 1.46

Wypisz cztery przykładowe łańcuchy opisywane przez wyrażenie $\mathbf{a(a + b)^*bb}$. Czy można skonstruować (deterministyczną) maszynę Turinga, która akceptuje język

$$(36) \quad L = L(a(a + b)^*bb)$$

$$(37) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, q_A, q_R) = (\{q_0, q_1, q_2, q_3, q_4, q_5\}, \{a, b\}, \{a, b, \nabla\}, \delta, q_0, \{q_4\}, \{q_5\})$$

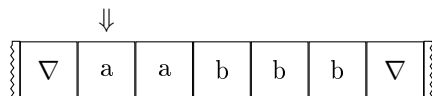


4.1.1 Przykładowe łańcuchy

1. abb
2. aabb
3. abbb
4. aabbb

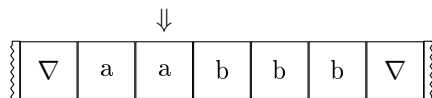
4.1.2 aabbb

1.



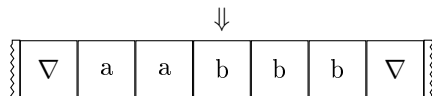
$$K_0 \quad q_0 aabbb \vdash$$

2.



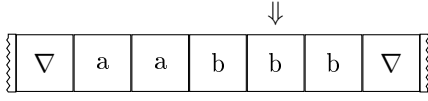
$$K_1 \quad aq_1 abbb \vdash$$

3.



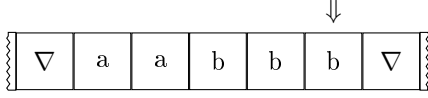
$$K_2 \quad aaq_1 bbb \vdash$$

4.



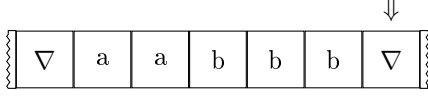
$K_3 \quad aabq_1bb \vdash$

5.



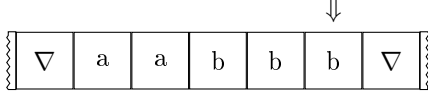
$K_4 \quad aabbq_1b \vdash$

6.



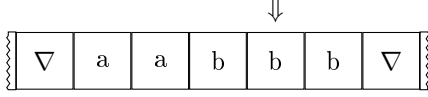
$K_5 \quad aabbbbq_1\nabla \vdash$

7.



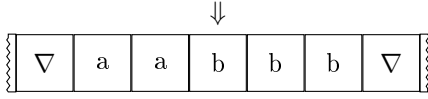
$K_6 \quad aabbq_2b \vdash$

8.



$K_7 \quad aabq_3bb \vdash$

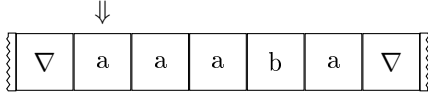
9.



$K_8 \quad aaq_4bbb$

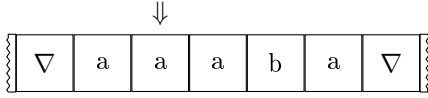
4.1.3 aaaba

1.



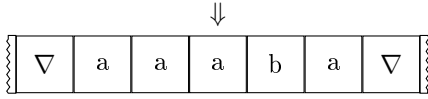
$K_0 \quad q_0aaaba \vdash$

2.



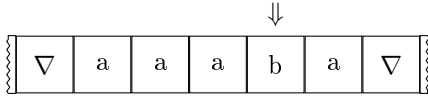
$K_1 \quad aq_1aaba \vdash$

3.



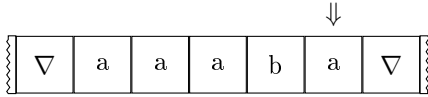
$K_2 \quad aaq_1aba \vdash$

4.



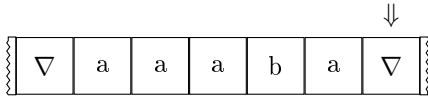
$K_3 \quad aaaq_1ba \vdash$

5.



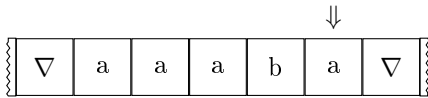
$K_4 \quad aaabq_1a \vdash$

6.



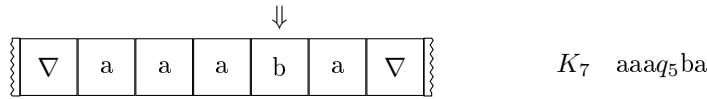
$K_5 \quad aaabaq_1\nabla \vdash$

7.



$K_6 \quad aaabq_2a \vdash$

8.



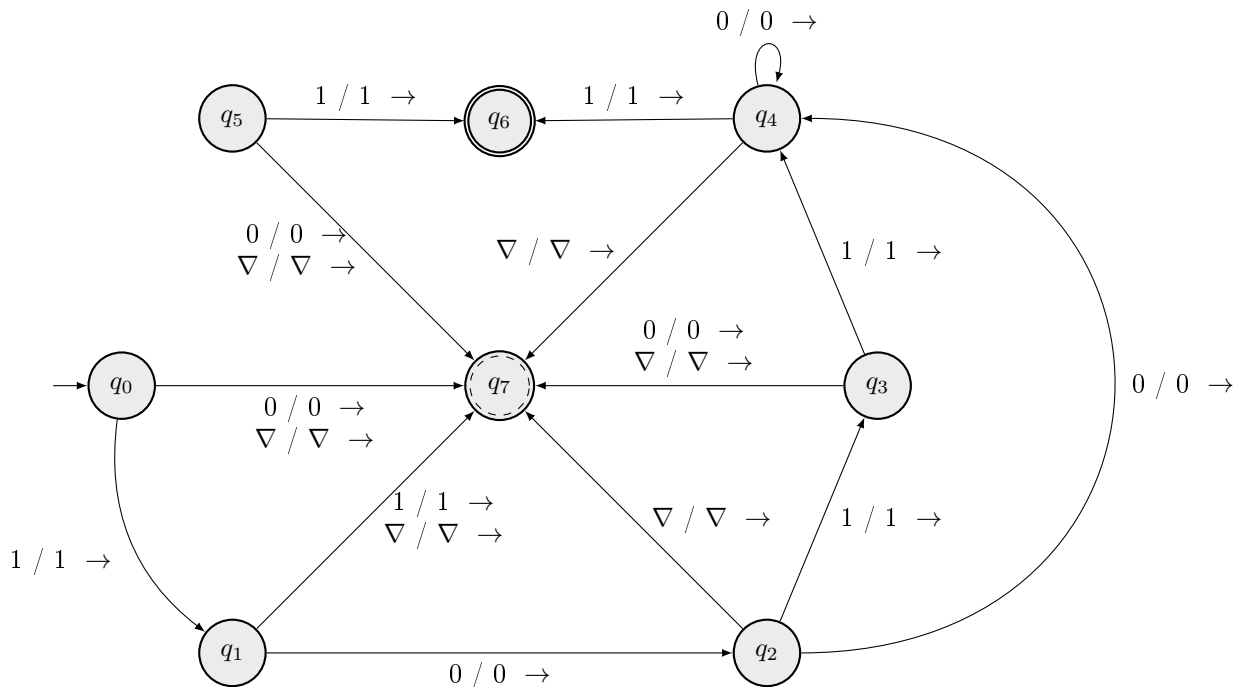
4.2 Zadanie 1.47

Wypisz cztery przykładowe łańcuchy opisywane przez wyrażenie $10 + (0 + 11)0^*1$. Czy można skonstruować (deterministyczną) maszynę Turinga, która akceptuje język

$$(38) \quad L = L(10 + (0 + 11)0^*1)$$

Jeżeli można, to narysuj diagram przejść i dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśmy i zapisz konfiguracje).

$$(39) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, q_A, q_R) = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6, q_7\}, \{1, 0\}, \{1, 0, \nabla\}, \delta, q_0, \{q_6\}, \{q_7\})$$

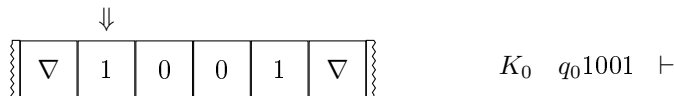


4.2.1 Przykładowe łańcuchy

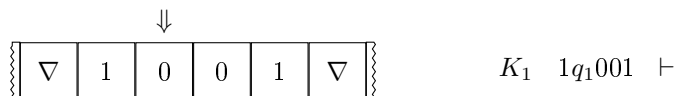
1. 1001
2. 10111
3. 100001
4. 101101

4.2.2 1001

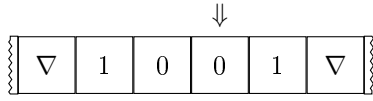
1.



2.

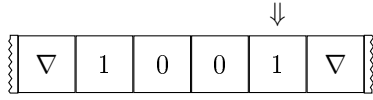


3.



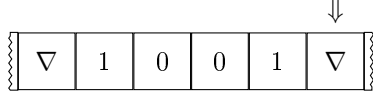
$K_2 \quad 10q_201 \quad \vdash$

4.



$K_3 \quad 100q_41 \quad \vdash$

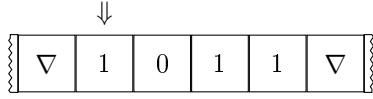
5.



$K_4 \quad 1001q_6\nabla$

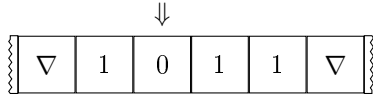
4.2.3 1011

1.



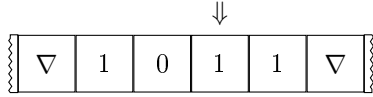
$K_0 \quad q_01011 \quad \vdash$

2.



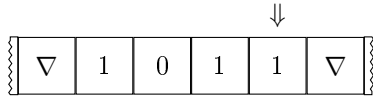
$K_1 \quad 1q_1011 \quad \vdash$

3.



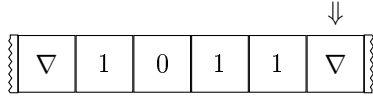
$K_2 \quad 10q_211 \quad \vdash$

4.



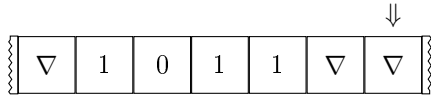
$K_3 \quad 101q_31 \quad \vdash$

5.



$K_4 \quad 1011q_4\nabla \quad \vdash$

6.



$K_5 \quad 1011\nabla q_7\nabla$

5 Zadania z wielotaśmowej maszyny Turinga

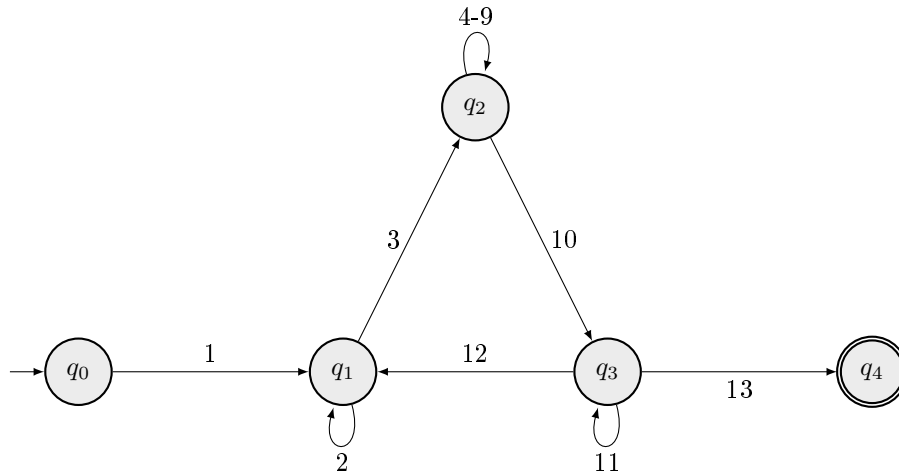
5.1 Zadanie 1.51

Używając unarnej reprezentacji liczb, zaprojektuj wielotaśmową maszynę Turinga, która oblicza funkcję

$$(40) \quad f(n) = \lceil \log_2 n \rceil.$$

Podaj tabelę przejść i narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśm i zapisz konfiguracje).

$$(41) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4\}, \{1\}, \{1, \nabla\}, \delta, q_0, \nabla, \{q_4\})$$

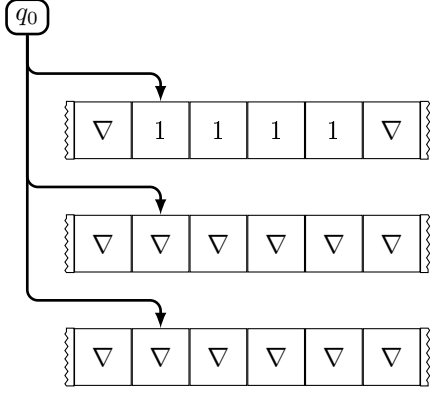


Nr	Stan bieżący	Czytany symbol	Nowy symbol	Nowy stan	Kierunki głowic
1	q_0	$[1, \nabla, \nabla]$	$[\nabla, 1, 1]$	q_1	$[\rightarrow, \rightarrow, \rightarrow]$
2	q_1	$[1, 1, \nabla]$	$[1, 1, 1]$	q_1	$[\rightarrow, \rightarrow, \rightarrow]$
3	q_1	$[1, \nabla, \nabla]$	$[1, 1, \nabla]$	q_2	$[\leftarrow, \leftarrow, \leftarrow]$
4	q_2	$[1, 1, 1]$	$[1, 1, 1]$	q_2	$[\leftarrow, \leftarrow, \leftarrow]$
5	q_2	$[\nabla, 1, 1]$	$[\nabla, 1, 1]$	q_2	$[\rightarrow, \leftarrow, \leftarrow]$
6	q_2	$[1, \nabla, 1]$	$[1, \nabla, 1]$	q_2	$[\leftarrow, \rightarrow, \leftarrow]$
7	q_2	$[1, 1, \nabla]$	$[1, 1, \nabla]$	q_2	$[\leftarrow, \leftarrow, \rightarrow]$
8	q_2	$[\nabla, \nabla, 1]$	$[\nabla, \nabla, 1]$	q_2	$[\rightarrow, \rightarrow, \leftarrow]$
9	q_2	$[1, \nabla, \nabla]$	$[1, \nabla, \nabla]$	q_2	$[\leftarrow, \rightarrow, \rightarrow]$
10	q_2	$[\nabla, \nabla, \nabla]$	$[\nabla, \nabla, \nabla]$	q_3	$[\rightarrow, \rightarrow, \rightarrow]$
11	q_3	$[1, 1, 1]$	$[1, 1, 1]$	q_3	$[\rightarrow, \rightarrow, \rightarrow]$
12	q_3	$[1, 1, \nabla]$	$[1, 1, \nabla]$	q_1	$[\rightarrow, \rightarrow, \rightarrow]$
13	q_3	$[\nabla, 1, 1]$	$[\nabla, 1, 1]$	q_4	$[\rightarrow, \rightarrow, \rightarrow]$

Wynik na środkowej taśmie

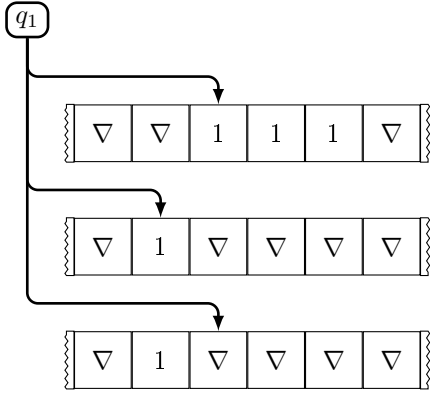
5.1.1 f(3)

1.



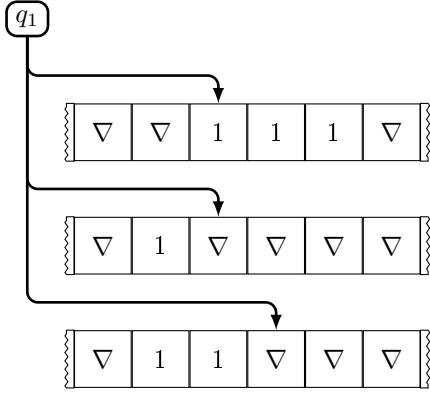
$$K_0 = (q_0, \uparrow 1111, \uparrow \nabla, \uparrow \nabla)$$

2.



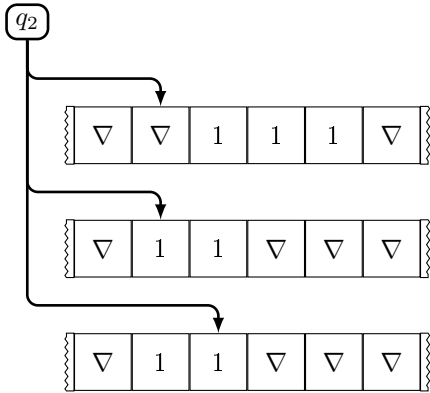
$$K_1 = (q_1, \uparrow 111, \uparrow 1, 1 \uparrow \nabla)$$

3.



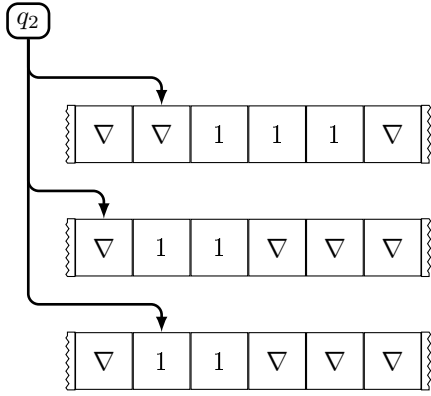
$$K_2 = (q_1, \uparrow 111, 1 \uparrow \nabla, 11 \uparrow \nabla)$$

4.



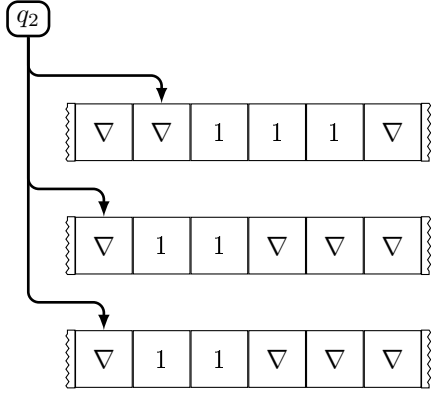
$$K_3 = (q_2, \uparrow \nabla 111, \uparrow 11, 1 \uparrow 1)$$

5.



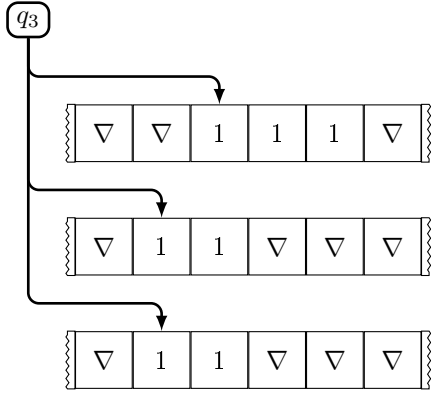
$$K_4 = (q_2, \uparrow\nabla 111, \uparrow\nabla 11, \uparrow 11)$$

6.



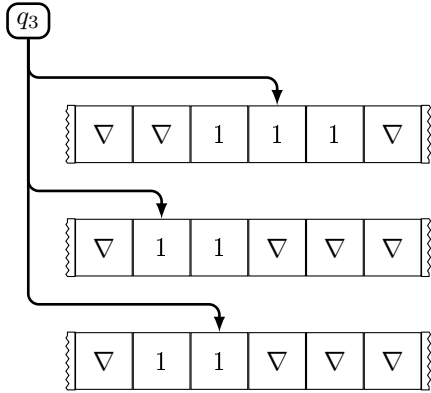
$$K_5 = (q_2, \uparrow\nabla 111, \uparrow\nabla 11, \uparrow\nabla 11)$$

7.



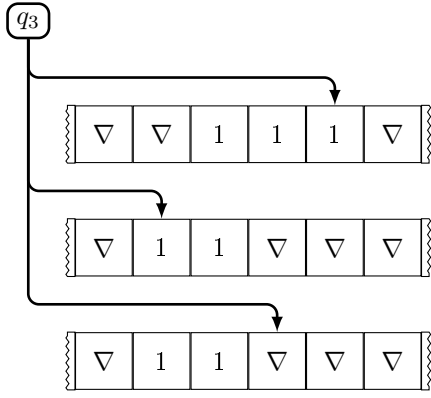
$$K_6 = (q_3, \uparrow 111, \uparrow 11, \uparrow 11)$$

8.



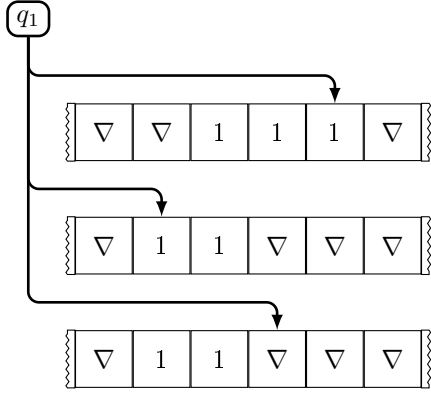
$$K_7 = (q_3, 1\uparrow 11, \uparrow 11, 1\uparrow 1)$$

9.



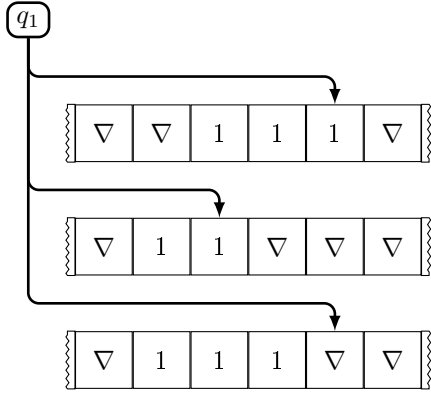
$$K_8 = (q_3, 11\uparrow 1, \uparrow 11, 11\uparrow \nabla)$$

10.



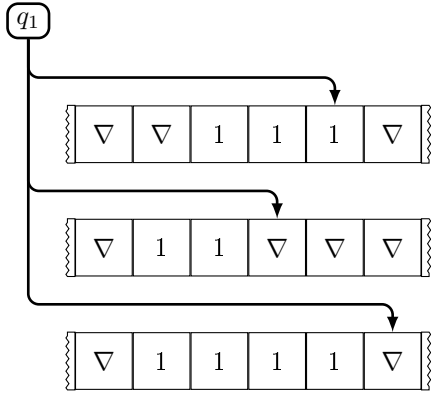
$$K_9 = (q_1, 11\uparrow 1, \uparrow 11, 11\uparrow \nabla)$$

11.



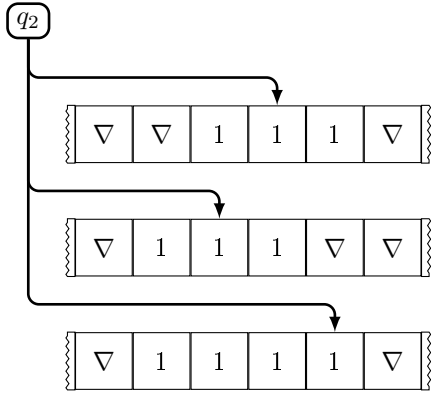
$$K_{10} = (q_1, 11\uparrow 1, 1\uparrow 1, 111\uparrow \nabla)$$

12.



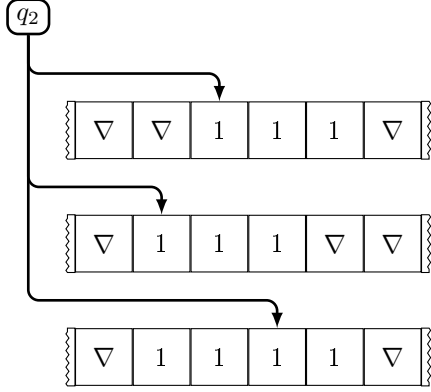
$$K_{11} = (q_1, 11\uparrow 1, 11\uparrow \nabla, 1111\uparrow \nabla)$$

13.



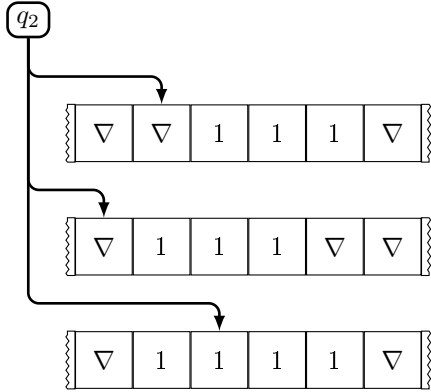
$$K_{12} = (q_2, 1\uparrow 11, 1\uparrow 11, 111\uparrow 1)$$

14.



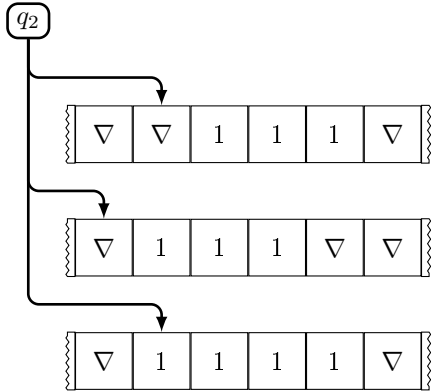
$$K_{13} = (q_2, \uparrow 111, \uparrow 111, 11\uparrow 11)$$

15.



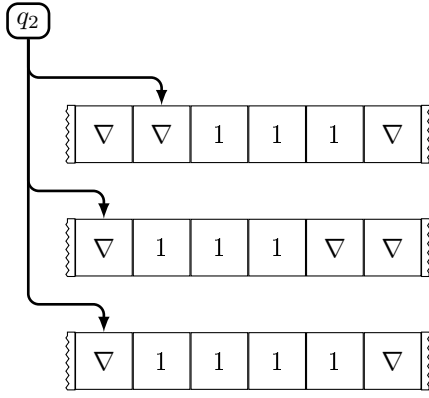
$$K_{14} = (q_2, \uparrow \nabla 111, \uparrow \nabla 111, 1\uparrow 111)$$

16.



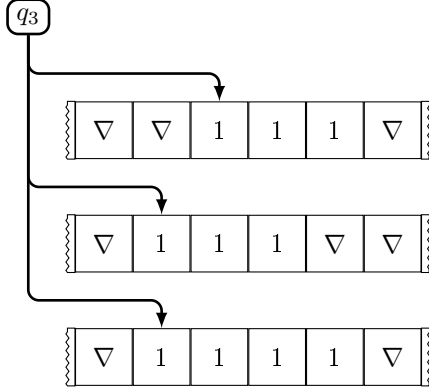
$$K_{15} = (q_2, \uparrow \nabla 111, \uparrow \nabla 111, \uparrow 1111)$$

17.



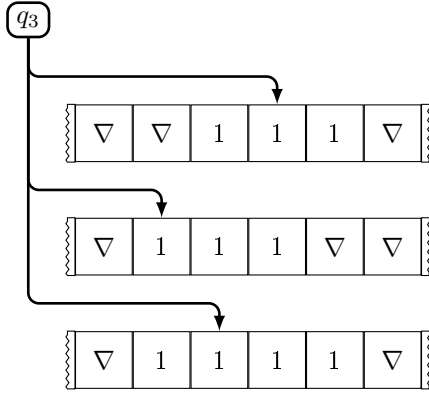
$$K_{16} = (q_2, \uparrow\nabla 111, \uparrow\nabla 111, \uparrow\nabla 1111)$$

18.



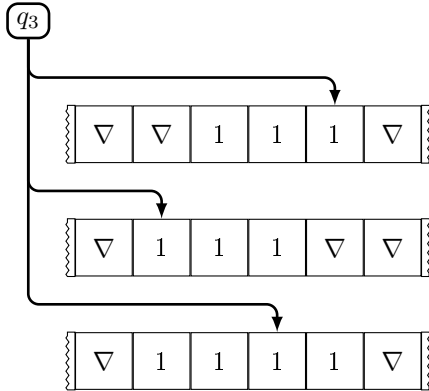
$$K_{17} = (q_3, \uparrow 111, \uparrow 111, \uparrow 1111)$$

19.



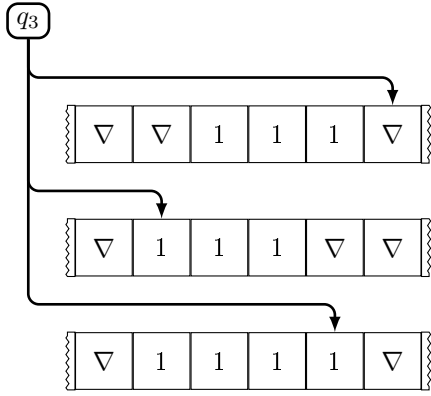
$$K_{18} = (q_3, 1\uparrow 11, \uparrow 111, 1\uparrow 111)$$

20.



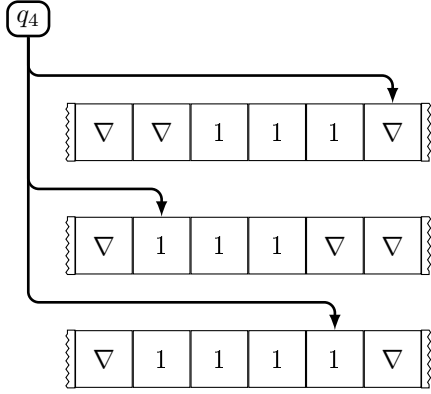
$$K_{19} = (q_3, 11\uparrow 1, \uparrow 111, 11\uparrow 11)$$

21.



$$K_{20} = (q_3, 111\uparrow\nabla, \uparrow 111, 111\uparrow 1)$$

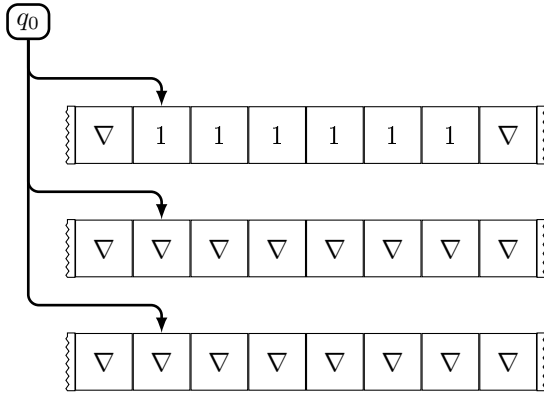
22.



$$K_{21} = (q_4, 111\uparrow\nabla, \uparrow 111, 111\uparrow 1)$$

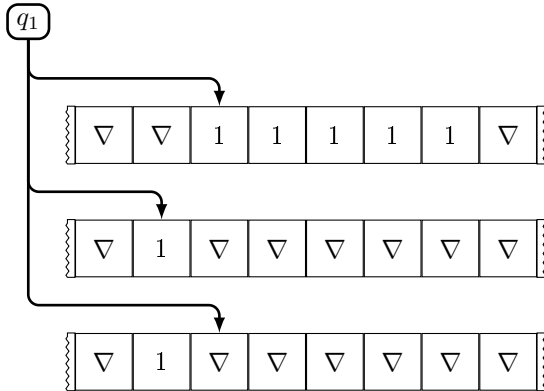
5.1.2 f(5)

1.



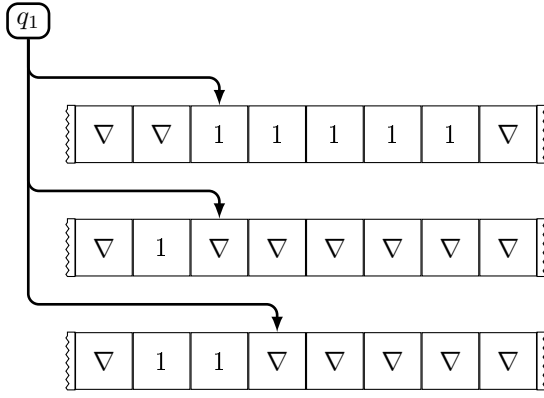
$$K_0 = (q_0, \uparrow 111111, \uparrow \nabla, \uparrow \nabla)$$

2.



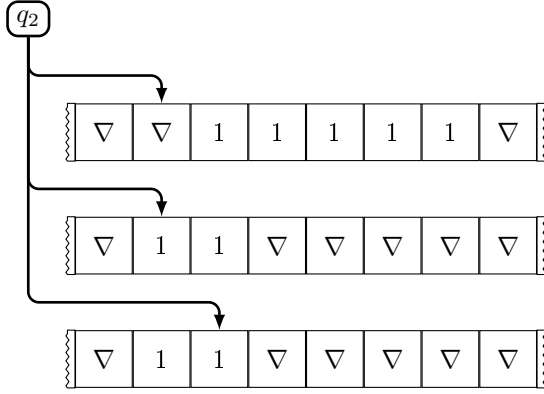
$$K_1 = (q_1, \uparrow 11111, \uparrow 1, 1\uparrow \nabla)$$

3.



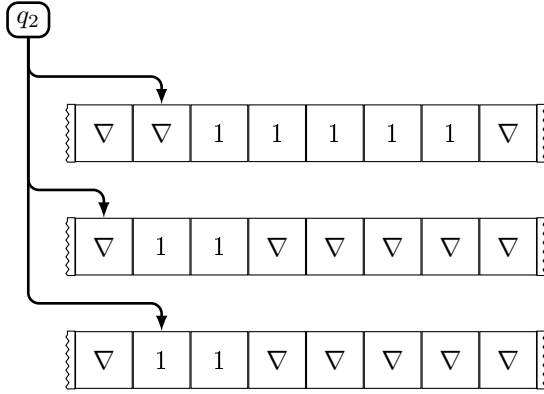
$$K_2 = (q_1, \uparrow 11111, 1\uparrow\nabla, 11\uparrow\nabla)$$

4.



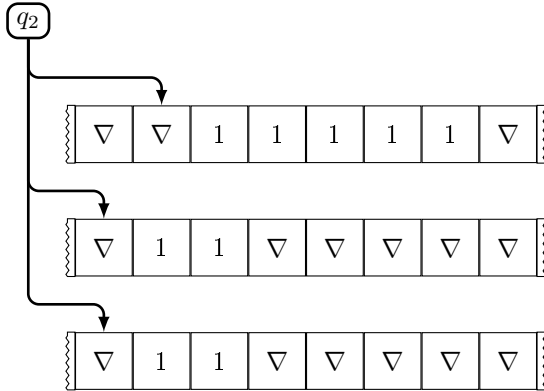
$$K_3 = (q_2, \uparrow \nabla 11111, \uparrow 11, 1\uparrow 1)$$

5.



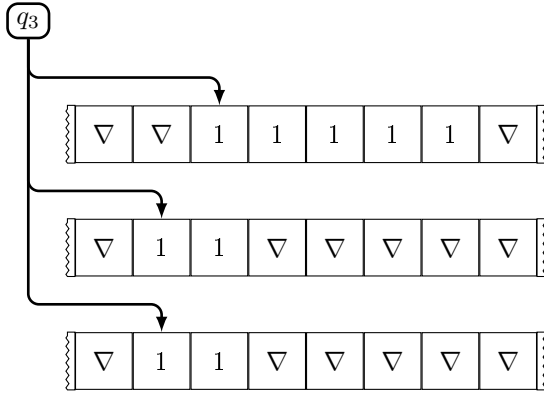
$$K_4 = (q_2, \uparrow \nabla 11111, \uparrow \nabla 11, \uparrow 11)$$

6.



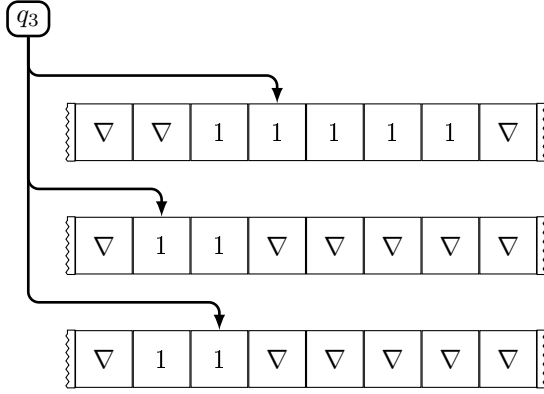
$$K_5 = (q_2, \uparrow \nabla 11111, \uparrow \nabla 11, \uparrow \nabla 11)$$

7.



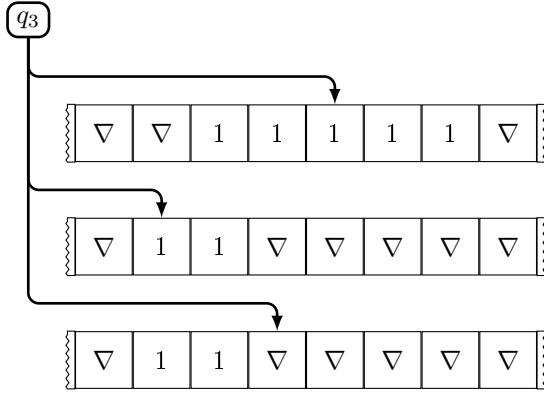
$$K_6 = (q_3, \uparrow 11111, \uparrow 11, \uparrow 11)$$

8.



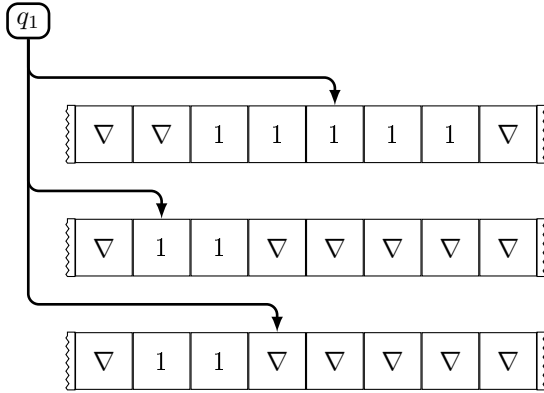
$$K_7 = (q_3, 1\uparrow 1111, \uparrow 11, 1\uparrow 1)$$

9.



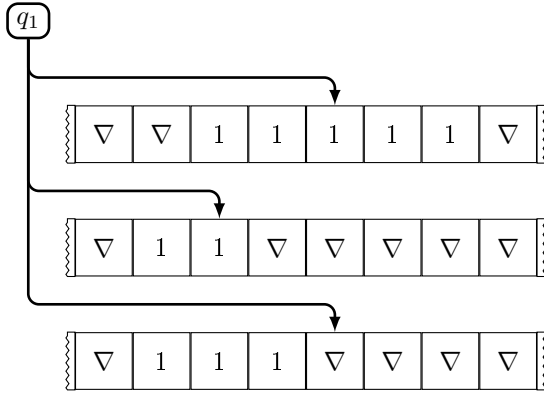
$$K_8 = (q_3, 11\uparrow 111, \uparrow 11, 11\uparrow \nabla)$$

10.



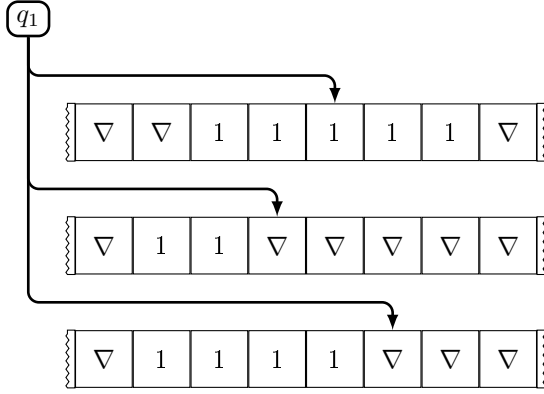
$$K_9 = (q_1, 11\uparrow 111, \uparrow 11, 11\uparrow \nabla)$$

11.



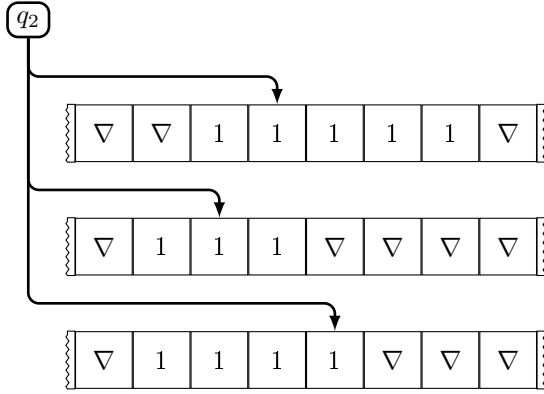
$$K_{10} = (q_1, 11\uparrow 111, 1\uparrow 1, 111\uparrow \nabla)$$

12.



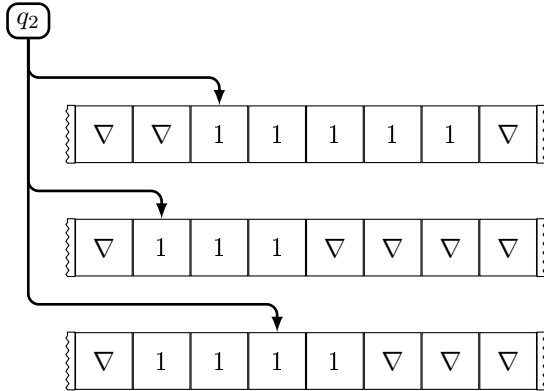
$$K_{11} = (q_1, 11\uparrow 111, 11\uparrow \nabla, 111\uparrow \nabla)$$

13.



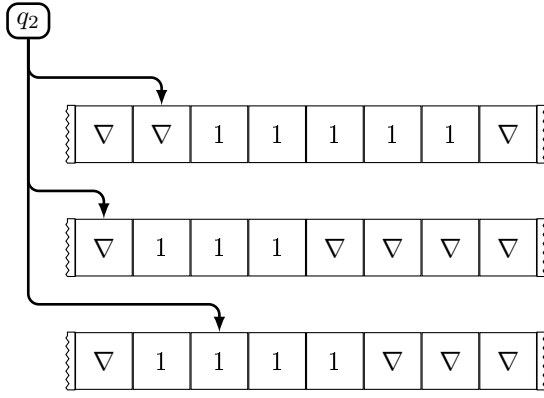
$$K_{12} = (q_2, 1\uparrow 1111, 1\uparrow 11, 111\uparrow 1)$$

14.



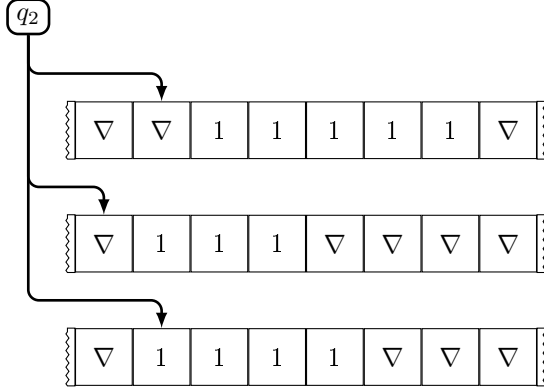
$$K_{13} = (q_2, \uparrow 11111, \uparrow 111, 11\uparrow 11)$$

15.



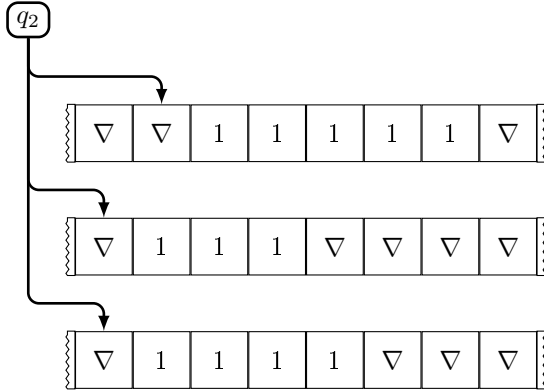
$$K_{14} = (q_2, \uparrow \nabla 11111, \uparrow \nabla 111, 1 \uparrow 111)$$

16.



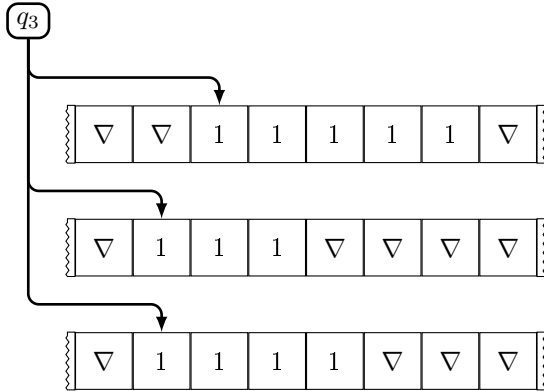
$$K_{15} = (q_2, \uparrow \nabla 11111, \uparrow \nabla 111, \uparrow 1111)$$

17.



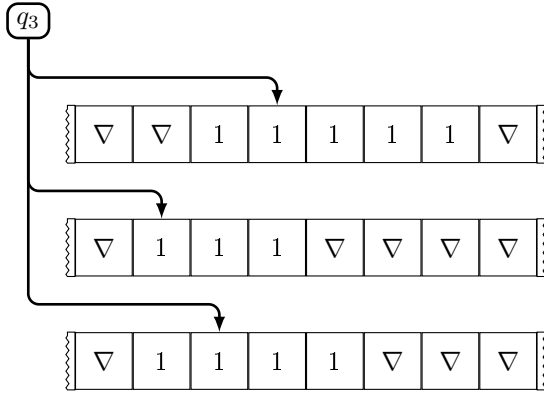
$$K_{16} = (q_2, \uparrow \nabla 11111, \uparrow \nabla 111, \uparrow \nabla 1111)$$

18.



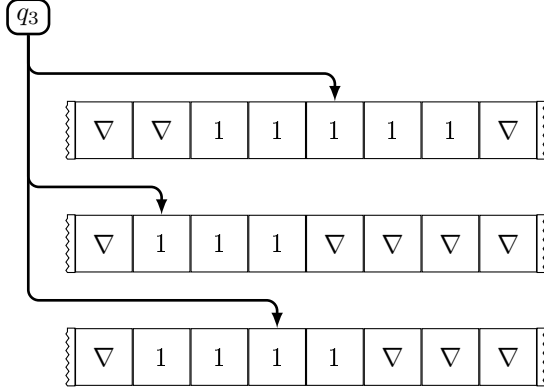
$$K_{17} = (q_3, \uparrow 11111, \uparrow 111, \uparrow 1111)$$

19.



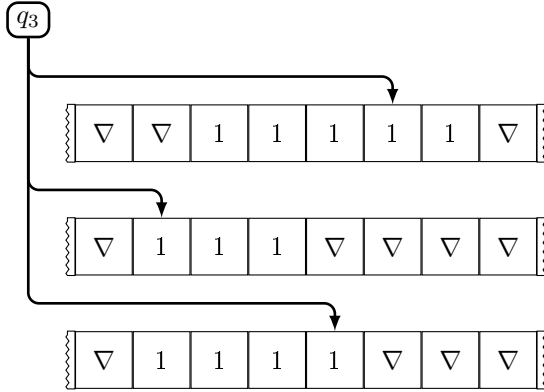
$$K_{18} = (q_3, 1\uparrow 1111, \uparrow 111, 1\uparrow 111)$$

20.



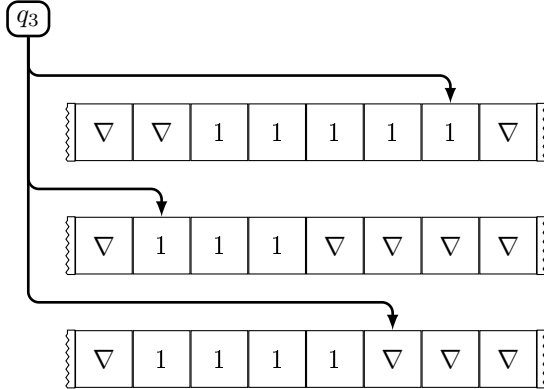
$$K_{19} = (q_3, 11\uparrow 111, \uparrow 111, 11\uparrow 11)$$

21.



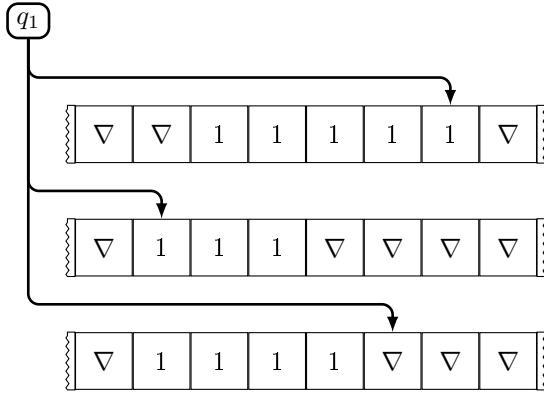
$$K_{20} = (q_3, 111\uparrow 11, \uparrow 111, 111\uparrow 1)$$

22.



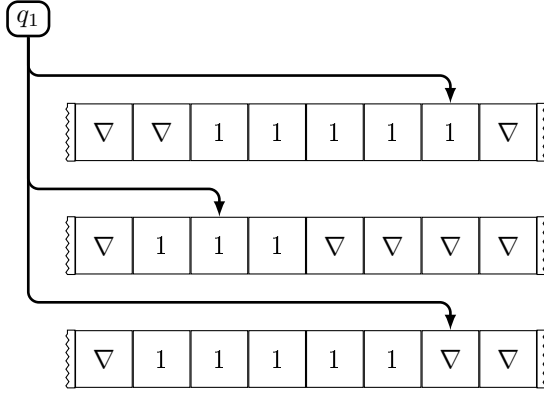
$$K_{21} = (q_3, 1111\uparrow 1, \uparrow 111, 1111\uparrow \nabla)$$

23.



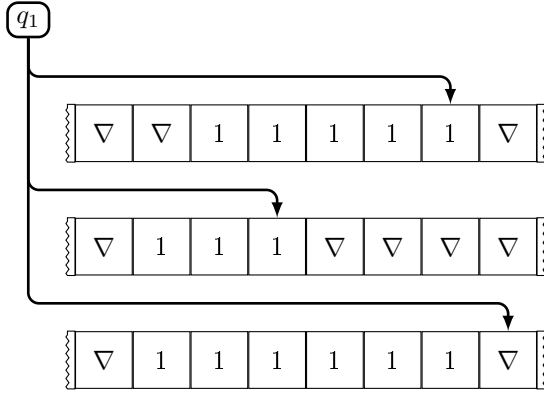
$$K_{22} = (q_1, 1111\uparrow 1, \uparrow 111, 1111\uparrow \nabla)$$

24.



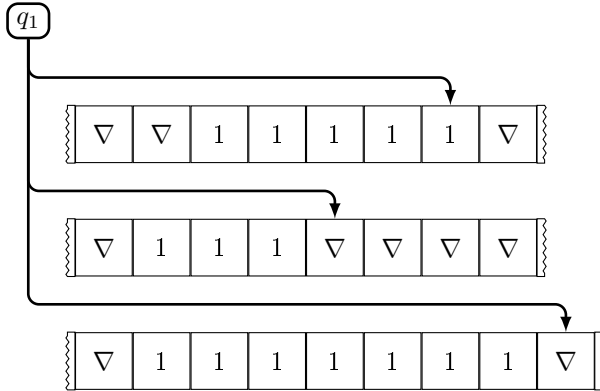
$$K_{23} = (q_1, 1111\uparrow 1, 1\uparrow 11, 11111\uparrow \nabla)$$

25.



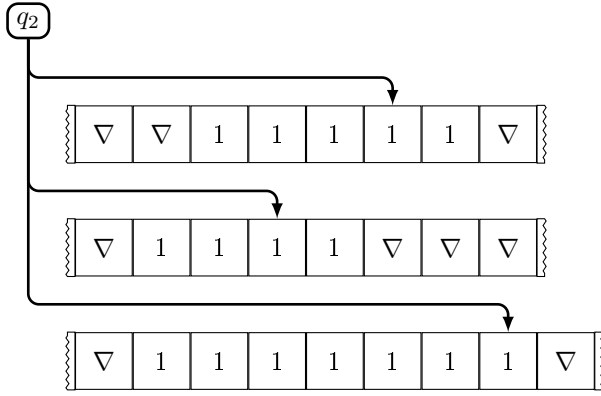
$$K_{24} = (q_1, 1111\uparrow 1, 11\uparrow 1, 111111\uparrow \nabla)$$

26.



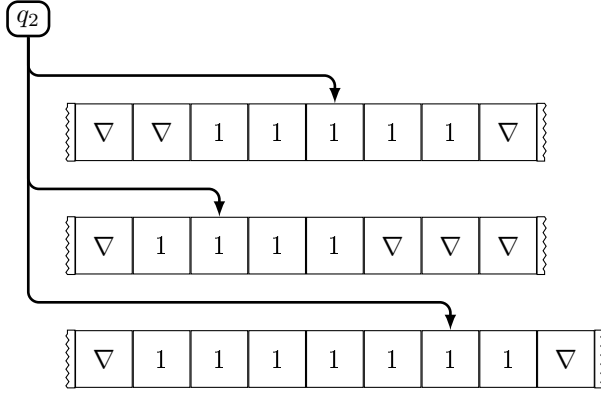
$$K_{25} = (q_1, 1111\uparrow 1, 111\uparrow \nabla, 1111111\uparrow \nabla)$$

27.



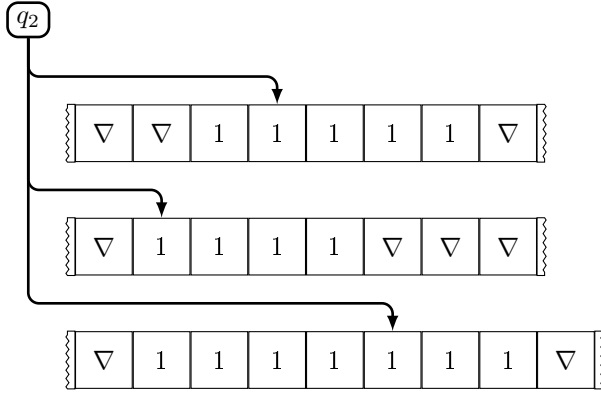
$$K_{26} = (q_2, 111\uparrow 11, 11\uparrow 11, 111111\uparrow 1)$$

28.



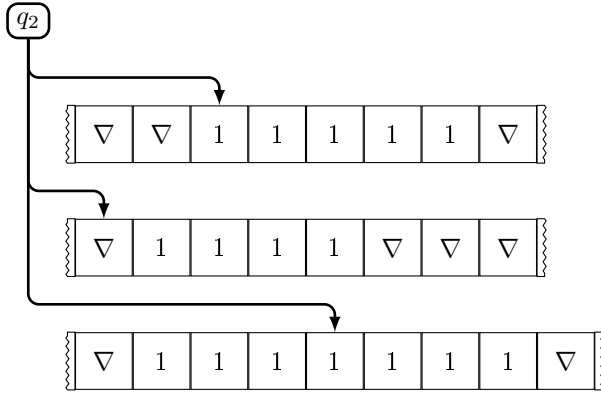
$$K_{27} = (q_2, 11\uparrow 111, 1\uparrow 111, 11111\uparrow 11)$$

29.



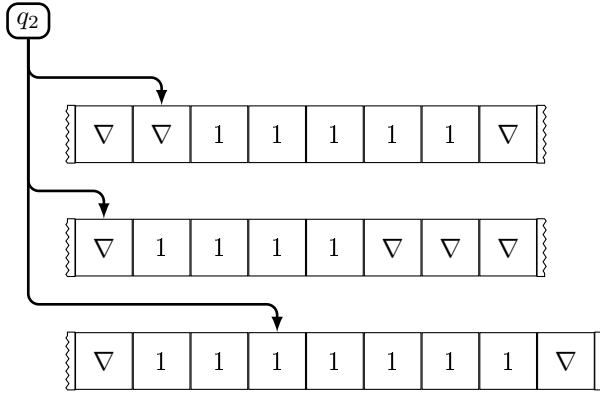
$$K_{28} = (q_2, 1\uparrow 1111, \uparrow 1111, 1111\uparrow 111)$$

30.



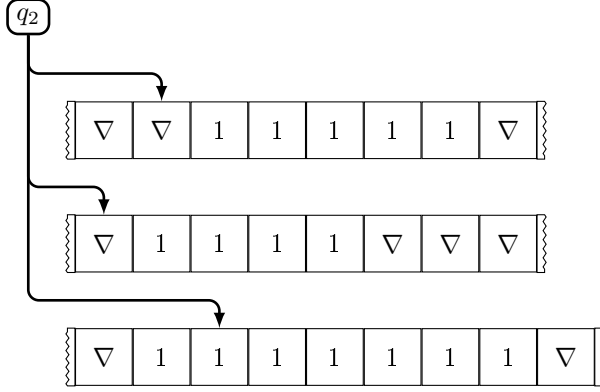
$$K_{29} = (q_2, \uparrow 11111, \uparrow \nabla 1111, 111\uparrow 1111)$$

31.



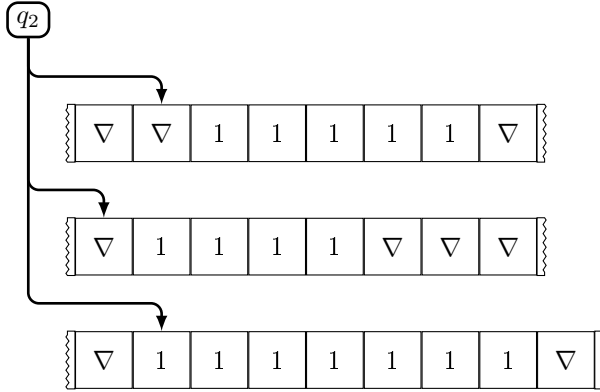
$$K_{30} = (q_2, \uparrow \nabla 11111, \uparrow \nabla 1111, 11 \uparrow 11111)$$

32.



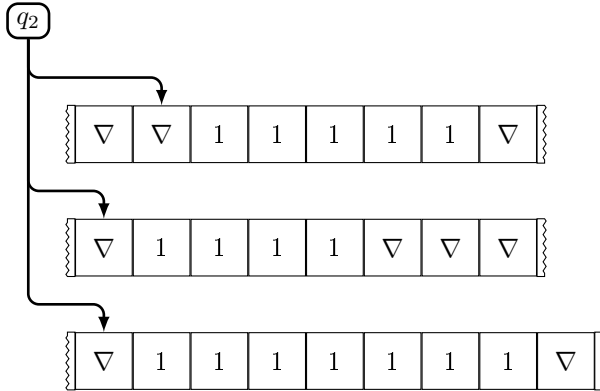
$$K_{31} = (q_2, \uparrow \nabla 11111, \uparrow \nabla 1111, 1 \uparrow 11111)$$

33.



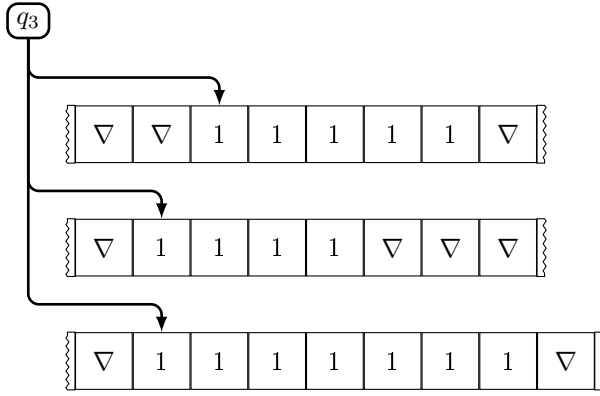
$$K_{32} = (q_2, \uparrow \nabla 11111, \uparrow \nabla 1111, \uparrow 1111111)$$

34.



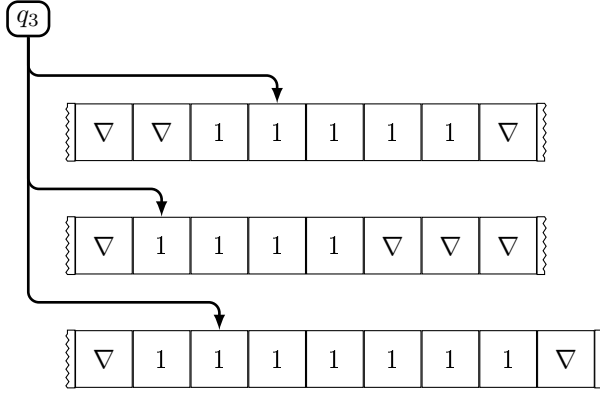
$$K_{33} = (q_2, \uparrow \nabla 11111, \uparrow \nabla 1111, \uparrow \nabla 1111111)$$

35.



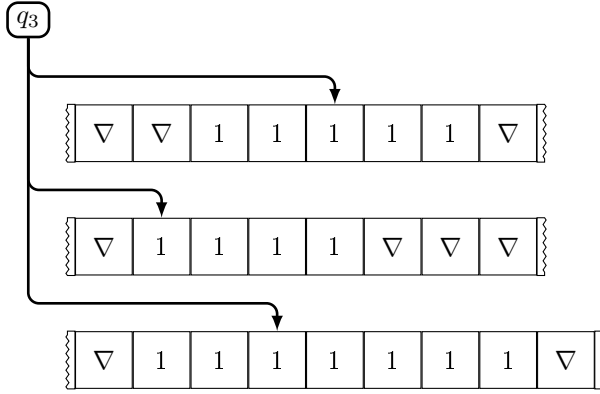
$$K_{34} = (q_3, \uparrow 11111, \uparrow 1111, \uparrow 1111111)$$

36.



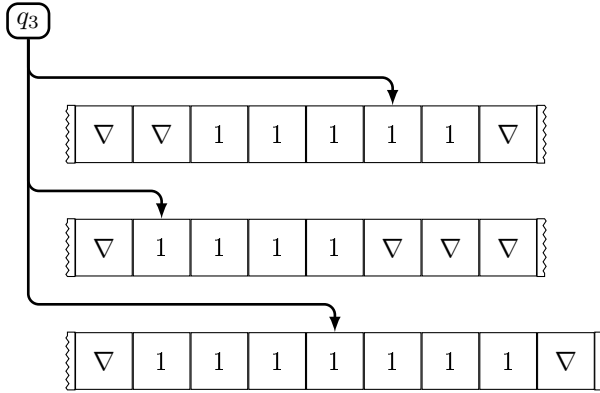
$$K_{35} = (q_3, 1\uparrow 1111, \uparrow 1111, 1\uparrow 111111)$$

37.



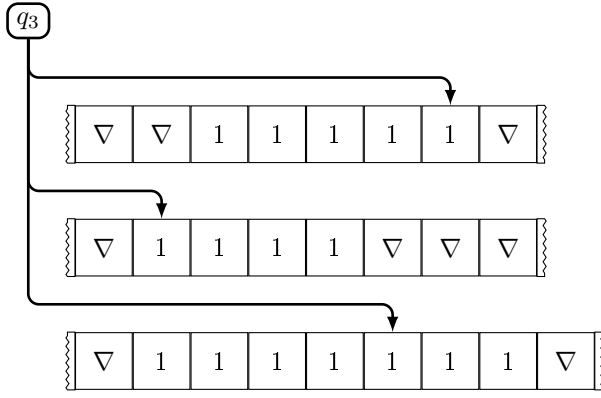
$$K_{36} = (q_3, 11\uparrow 111, \uparrow 1111, 11\uparrow 11111)$$

38.



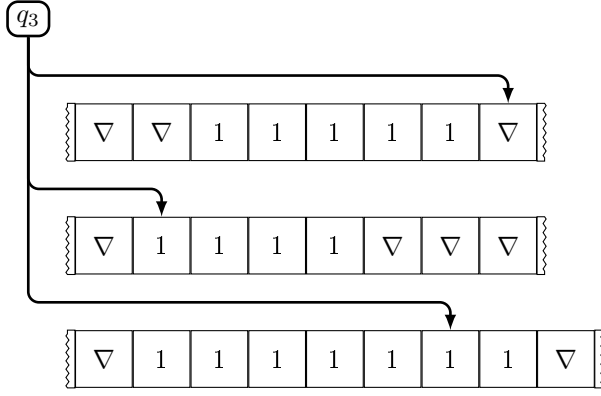
$$K_{37} = (q_3, 111\uparrow 11, \uparrow 1111, 111\uparrow 1111)$$

39.



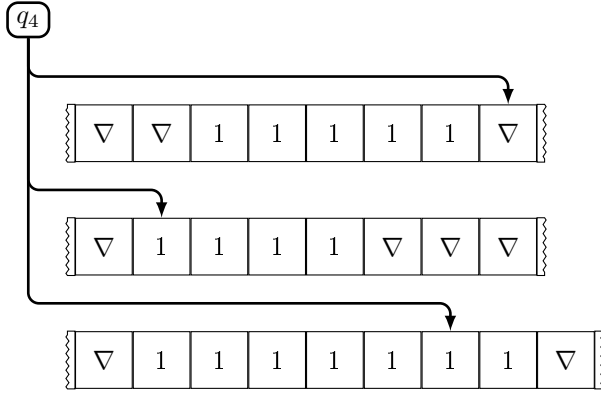
$$K_{38} = (q_3, 1111\uparrow 1, \uparrow 1111, 1111\uparrow 111)$$

40.



$$K_{39} = (q_3, 11111\uparrow \nabla, \uparrow 1111, 11111\uparrow 11)$$

41.



$$K_{40} = (q_4, 11111\uparrow \nabla, \uparrow 1111, 11111\uparrow 11)$$

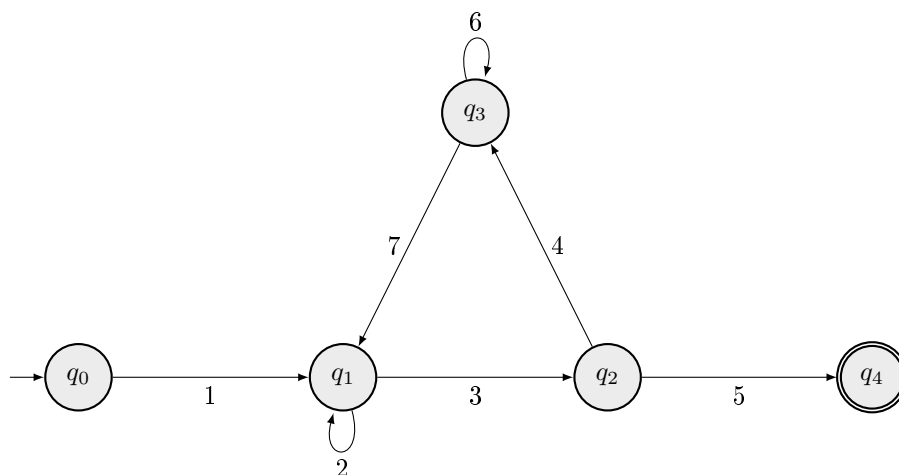
5.2 Zadanie 1.53

Używając unarnej reprezentacji liczb, zaprojektuj wielotaśmową maszynę Turinga, która oblicza funkcję

$$(42) \quad f(n) = n^2$$

Podaj tabelę przejść i narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśm i zapisz konfiguracje).

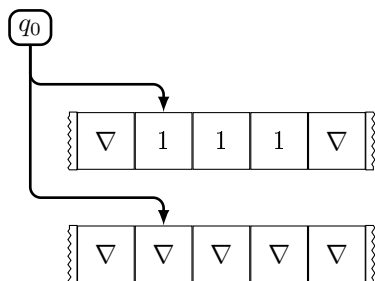
$$(43) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4\}, \{1\}, \{1, x, \nabla\}, \delta, q_0, \nabla, \{q_4\})$$



Nr	Stan bieżący	Czytany symbol	Nowy symbol	Nowy stan	Kierunki głowic
1	q_0	$[1, \nabla]$	$[B, B]$	q_1	$[\rightarrow, \text{—}]$
2	q_1	$[1, \nabla]$	$[x, 1]$	q_1	$[\rightarrow, \rightarrow]$
3	q_1	$[\nabla, \nabla]$	$[B, B]$	q_2	$[\leftarrow, \text{—}]$
4	q_2	$[x, \nabla]$	$[B, B]$	q_3	$[\leftarrow, \text{—}]$
5	q_2	$[\nabla, \nabla]$	$[B, 1]$	q_4	$[\text{—}, \text{—}]$
6	q_3	$[x, \nabla]$	$[1, 1]$	q_3	$[\leftarrow, \rightarrow]$
7	q_3	$[\nabla, \nabla]$	$[B, B]$	q_1	$[\rightarrow, \text{—}]$

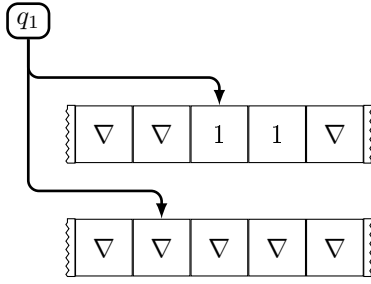
5.2.1 $f(2)$

1.



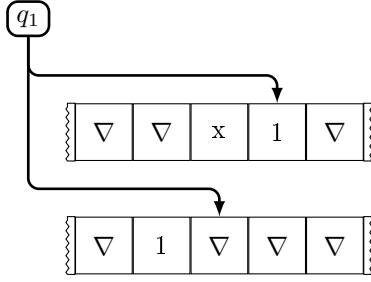
$$K_0 = (q_0, \uparrow 111, \uparrow \nabla)$$

2.



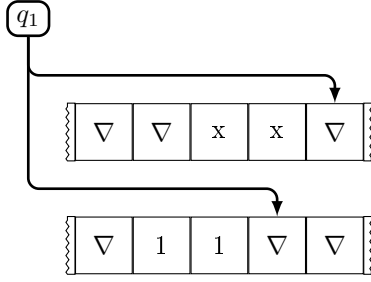
$$K_1 = (q_1, \uparrow 11, \uparrow \nabla)$$

3.



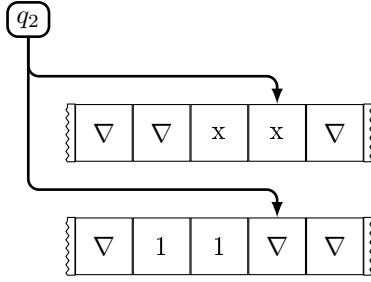
$$K_2 = (q_1, x\uparrow 1, 1\uparrow \nabla)$$

4.



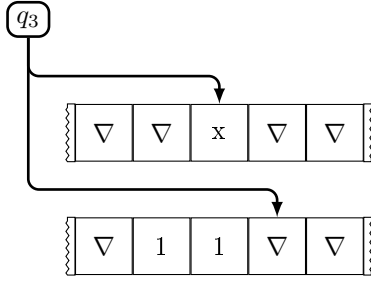
$$K_3 = (q_1, xx\uparrow \nabla, 11\uparrow \nabla)$$

5.



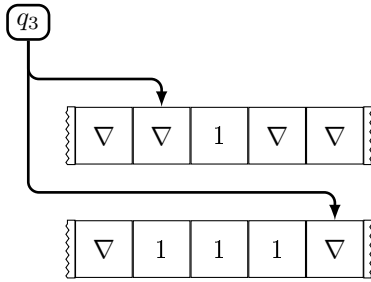
$$K_4 = (q_2, x\uparrow x, 11\uparrow \nabla)$$

6.



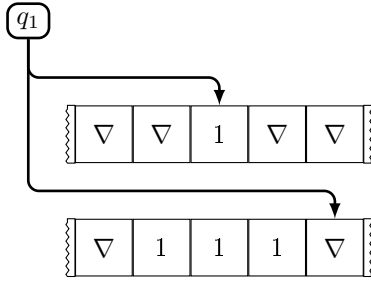
$$K_5 = (q_3, \uparrow x, 11\uparrow \nabla)$$

7.



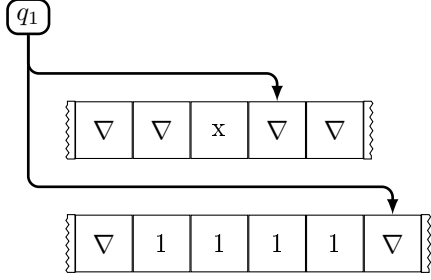
$$K_6 = (q_3, \uparrow \nabla 1, 111\uparrow \nabla)$$

8.



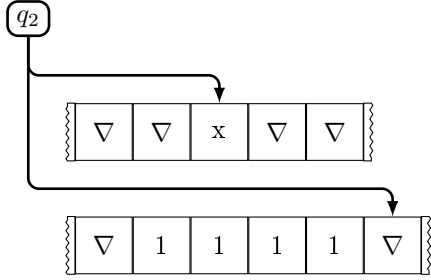
$$K_7 = (q_1, \uparrow 1, 111\uparrow\nabla)$$

9.



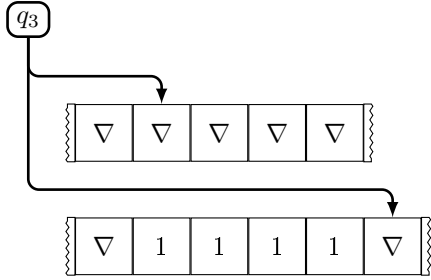
$$K_8 = (q_1, x\uparrow\nabla, 1111\uparrow\nabla)$$

10.



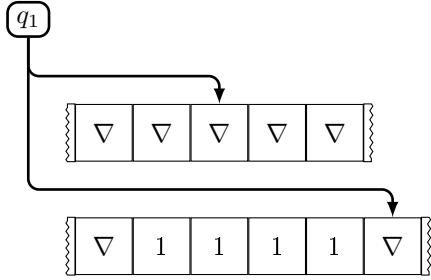
$$K_9 = (q_2, \uparrow x, 1111\uparrow\nabla)$$

11.



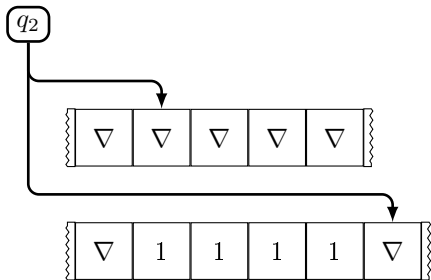
$$K_{10} = (q_3, \uparrow\nabla, 1111\uparrow\nabla)$$

12.



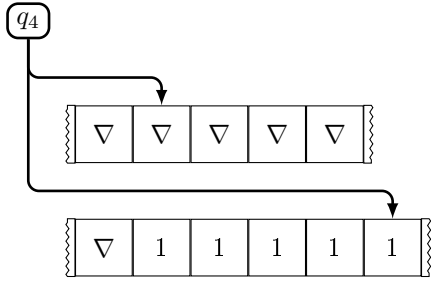
$$K_{11} = (q_1, \uparrow\nabla, 1111\uparrow\nabla)$$

13.



$$K_{12} = (q_2, \uparrow\nabla, 1111\uparrow\nabla)$$

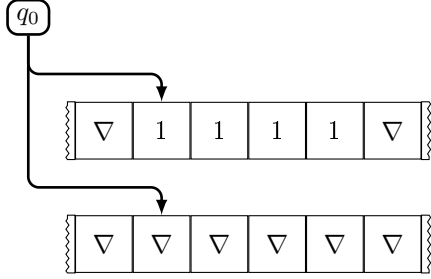
14.



$$K_{13} = (q_4, \uparrow\nabla, 1111\uparrow 1)$$

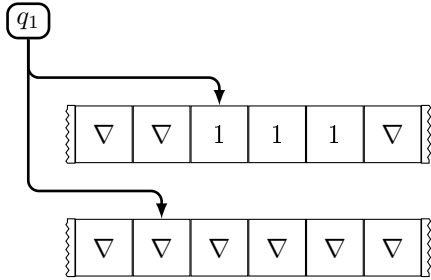
5.2.2 f(3)

1.



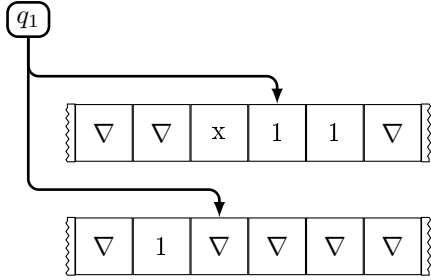
$$K_0 = (q_0, \uparrow 1111, \uparrow\nabla)$$

2.



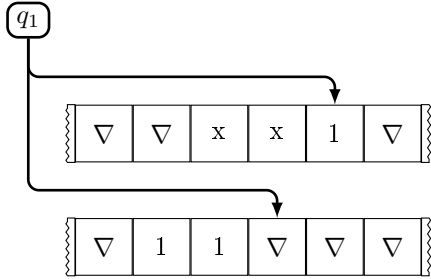
$$K_1 = (q_1, \uparrow 111, \uparrow\nabla)$$

3.



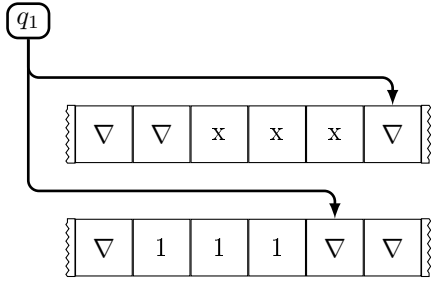
$$K_2 = (q_1, x\uparrow 11, 1\uparrow\nabla)$$

4.



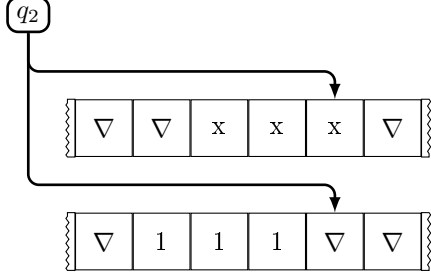
$$K_3 = (q_1, xx\uparrow 1, 11\uparrow\nabla)$$

5.



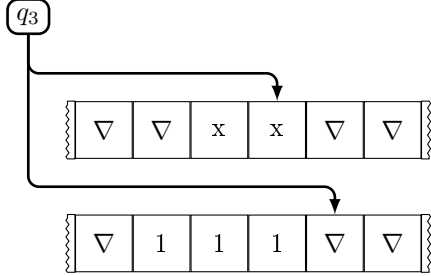
$$K_4 = (q_1, xxx\uparrow\nabla, 111\uparrow\nabla)$$

6.



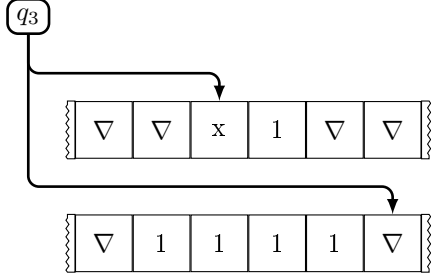
$$K_5 = (q_2, xx\uparrow x, 111\uparrow\nabla)$$

7.



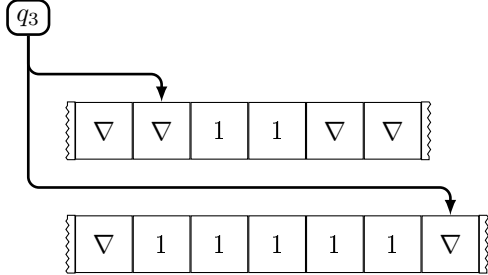
$$K_6 = (q_3, x\uparrow x, 111\uparrow\nabla)$$

8.



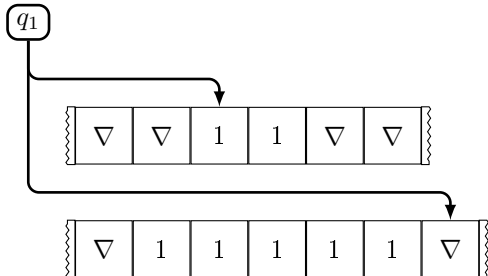
$$K_7 = (q_3, \uparrow x1, 1111\uparrow\nabla)$$

9.



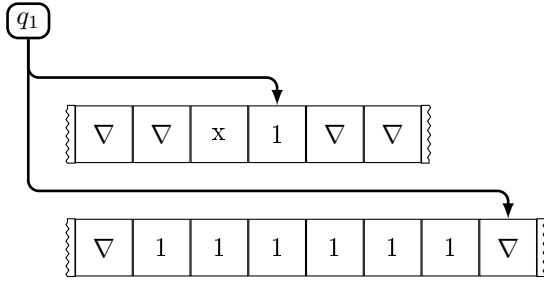
$$K_8 = (q_3, \uparrow\nabla11, 11111\uparrow\nabla)$$

10.



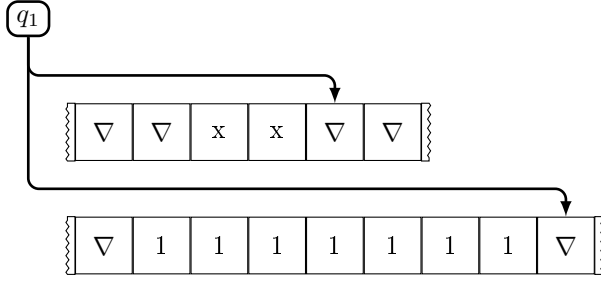
$$K_9 = (q_1, \uparrow11, 11111\uparrow\nabla)$$

11.



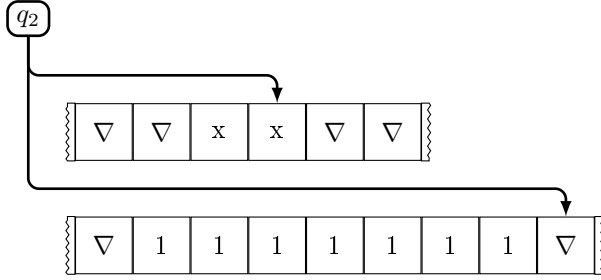
$$K_{10} = (q_1, x \uparrow 1, 111111 \uparrow \nabla)$$

12.



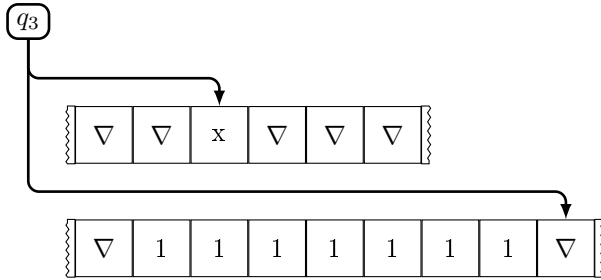
$$K_{11} = (q_1, xx \uparrow \nabla, 1111111 \uparrow \nabla)$$

13.



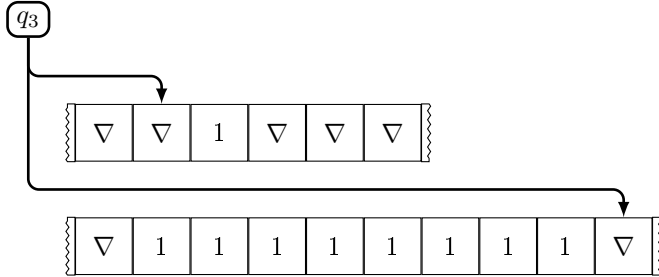
$$K_{12} = (q_2, x \uparrow x, 1111111 \uparrow \nabla)$$

14.



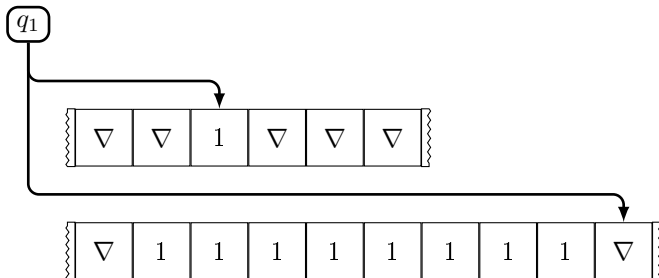
$$K_{13} = (q_3, \uparrow x, 1111111 \uparrow \nabla)$$

15.



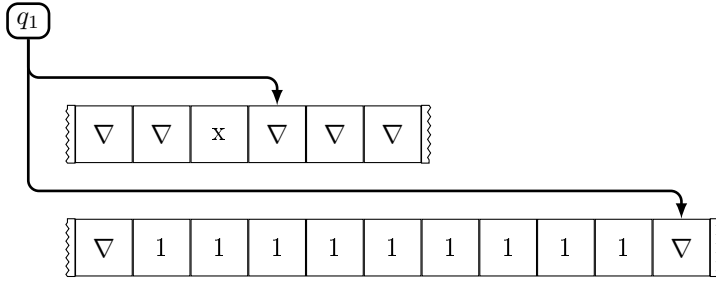
$$K_{14} = (q_3, \uparrow \nabla 1, 11111111 \uparrow \nabla)$$

16.



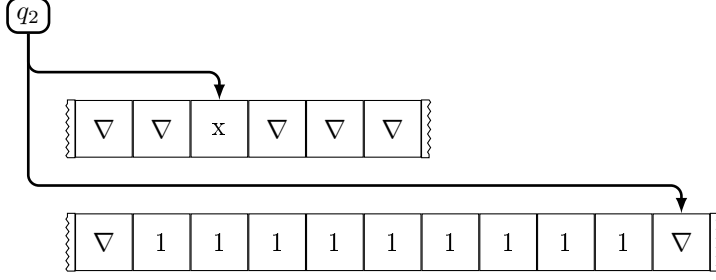
$$K_{15} = (q_1, \uparrow 1, 11111111 \uparrow \nabla)$$

17.



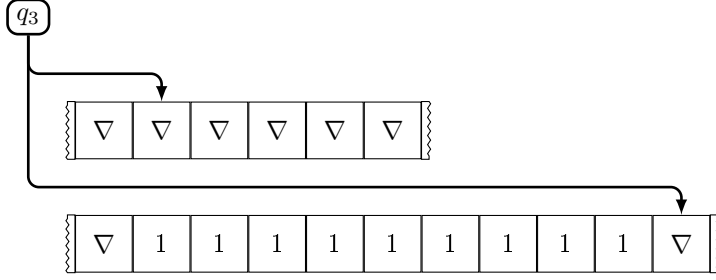
$$K_{16} = (q_1, x \uparrow \nabla, 111111111 \uparrow \nabla)$$

18.



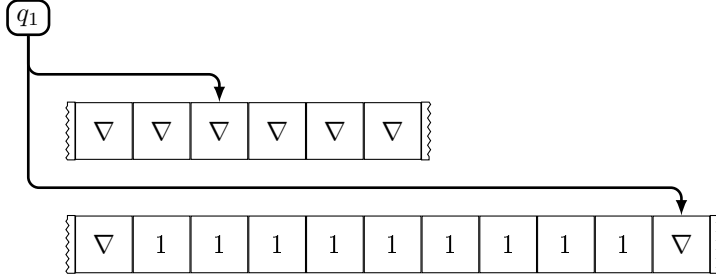
$$K_{17} = (q_2, \uparrow x, 111111111 \uparrow \nabla)$$

19.



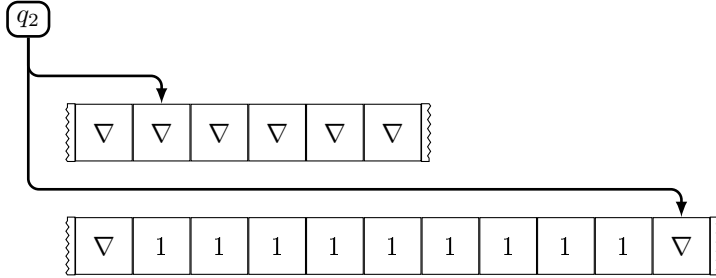
$$K_{18} = (q_3, \uparrow \nabla, 111111111 \uparrow \nabla)$$

20.



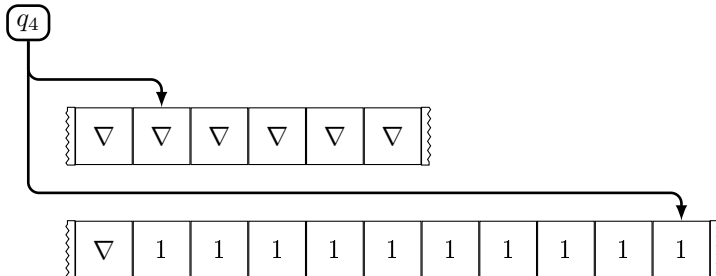
$$K_{19} = (q_1, \uparrow \nabla, 111111111 \uparrow \nabla)$$

21.



$$K_{20} = (q_2, \uparrow \nabla, 111111111 \uparrow \nabla)$$

22.



$$K_{21} = (q_4, \uparrow \nabla, 111111111 \uparrow 1)$$

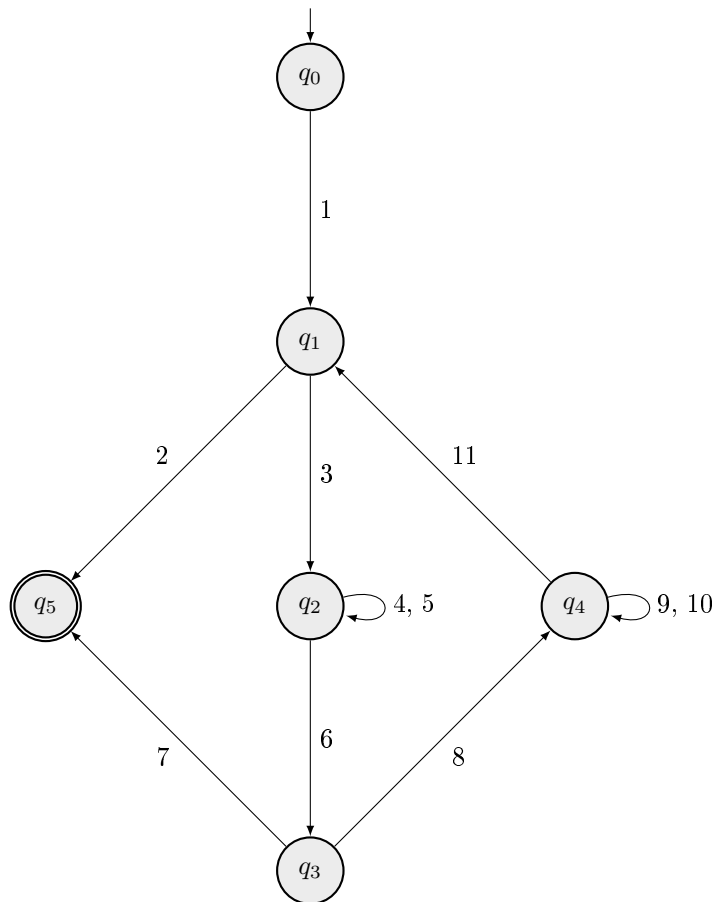
5.3 Zadanie 1.54

Zaprojektuj wielotaśmową maszynę Turinga, które oblicza funkcję mnożenia f dla liczb naturalnych m i n w reprezentacji unarnej

$$(44) \quad f(m, n) = m \cdot n$$

Podaj tabelę przejść i narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśm i zapisz konfiguracje).

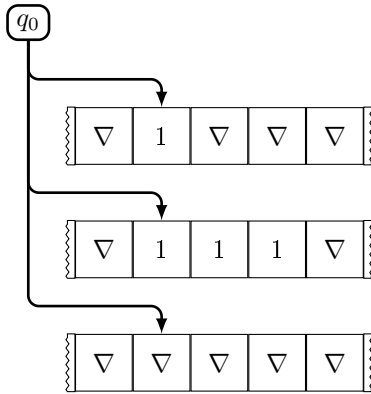
$$(45) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4, q_5\}, \{1\}, \{1, \nabla\}, \delta, q_0, \nabla, \{q_5\})$$



Nr	Stan bieżący	Czytany symbol	Nowy symbol	Nowy stan	Kierunki głowic
1	q_0	[1, 1, ∇]	[∇ , ∇ , ∇]	q_1	[\rightarrow , \rightarrow , \leftarrow]
2	q_1	[∇ , 1, ∇]	[∇ , 1, 1]	q_5	[\leftarrow , \leftarrow , \leftarrow]
3	q_1	[1, 1, ∇]	[∇ , 1, 1]	q_2	[\leftarrow , \rightarrow , \rightarrow]
4	q_2	[1, 1, ∇]	[∇ , 1, 1]	q_2	[\leftarrow , \rightarrow , \rightarrow]
5	q_2	[∇ , 1, ∇]	[∇ , 1, 1]	q_2	[\leftarrow , \rightarrow , \rightarrow]
6	q_2	[∇ , ∇ , ∇]	[∇ , ∇ , ∇]	q_3	[\rightarrow , \leftarrow , \leftarrow]
7	q_3	[∇ , 1, ∇]	[∇ , 1, 1]	q_5	[\leftarrow , \leftarrow , \leftarrow]
8	q_3	[1, 1, ∇]	[∇ , 1, 1]	q_4	[\leftarrow , \leftarrow , \rightarrow]
9	q_4	[1, 1, ∇]	[∇ , 1, 1]	q_4	[\leftarrow , \leftarrow , \rightarrow]
10	q_4	[∇ , 1, ∇]	[∇ , 1, 1]	q_4	[\leftarrow , \leftarrow , \rightarrow]
11	q_4	[∇ , ∇ , ∇]	[∇ , ∇ , ∇]	q_1	[\rightarrow , \rightarrow , \leftarrow]

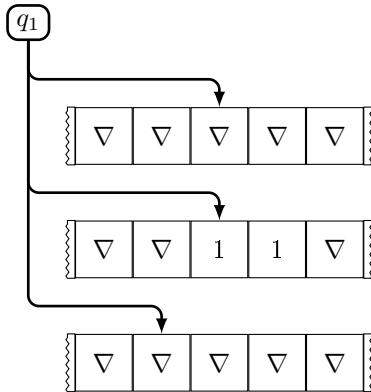
5.3.1 $f(0, 2)$

1.



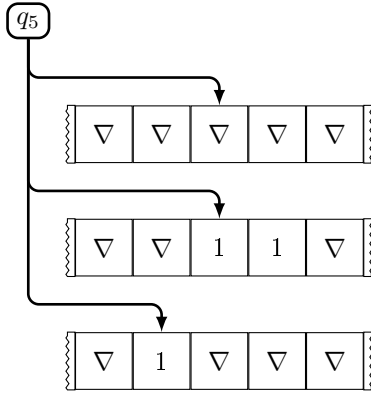
$$K_0 = (q_0, \uparrow 1, \uparrow 111, \uparrow \nabla)$$

2.



$$K_1 = (q_1, \uparrow \nabla, \uparrow 11, \uparrow \nabla)$$

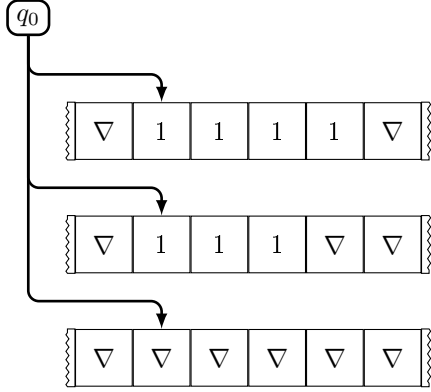
3.



$$K_2 = (q_5, \uparrow\nabla, \uparrow 11, \uparrow 1)$$

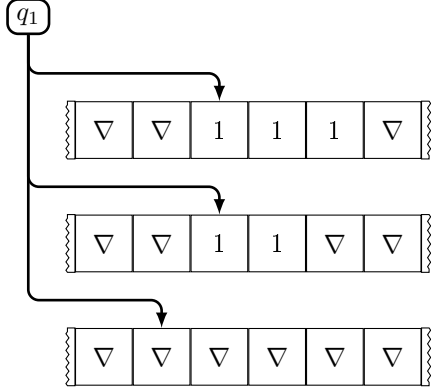
5.3.2 $f(3, 2)$

1.



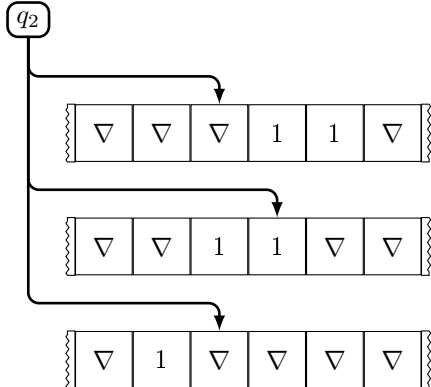
$$K_0 = (q_0, \uparrow 1111, \uparrow 111, \uparrow \nabla)$$

2.



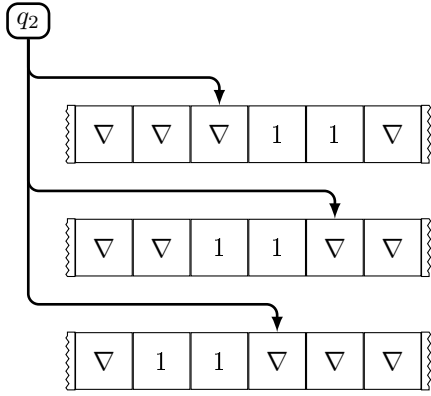
$$K_1 = (q_1, \uparrow 111, \uparrow 11, \uparrow \nabla)$$

3.



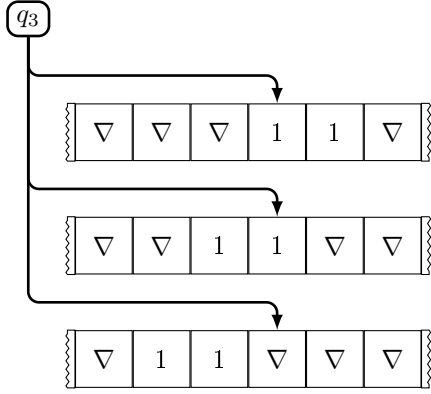
$$K_2 = (q_2, \uparrow \nabla 11, 1 \uparrow 1, 1 \uparrow \nabla)$$

4.



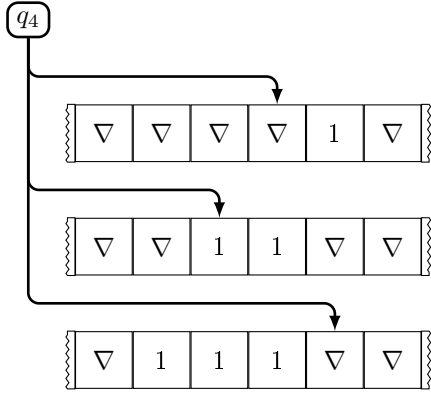
$$K_3 = (q_2, \uparrow \nabla 11, 11 \uparrow \nabla, 11 \uparrow \nabla)$$

5.



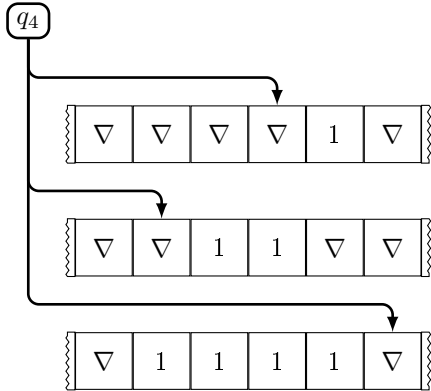
$$K_4 = (q_3, \uparrow 11, 1 \uparrow 1, 11 \uparrow \nabla)$$

6.



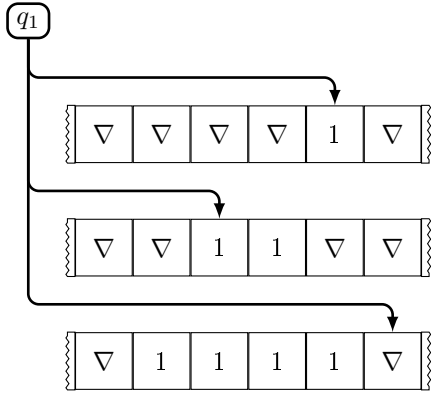
$$K_5 = (q_4, \uparrow \nabla 1, \uparrow 11, 111 \uparrow \nabla)$$

7.



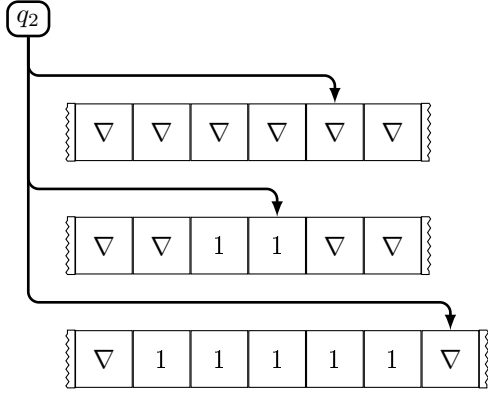
$$K_6 = (q_4, \uparrow \nabla 1, \uparrow \nabla 11, 1111 \uparrow \nabla)$$

8.



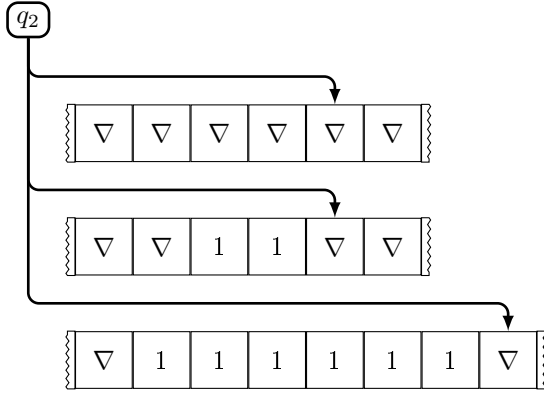
$$K_7 = (q_1, \uparrow 1, \uparrow 11, 1111 \uparrow \nabla)$$

9.



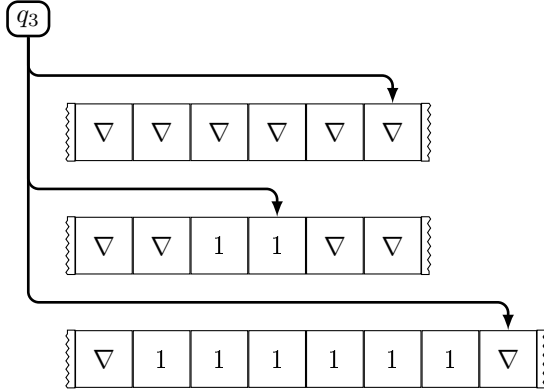
$$K_8 = (q_2, \uparrow \nabla, 1 \uparrow 1, 11111 \uparrow \nabla)$$

10.



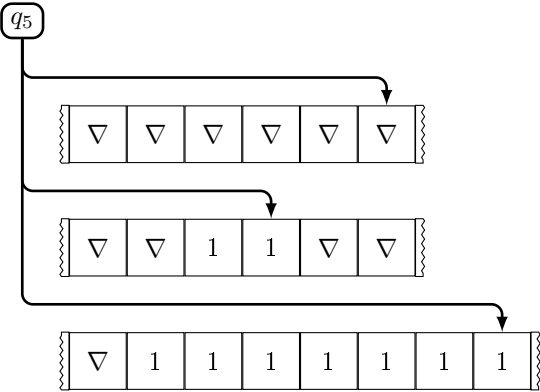
$$K_9 = (q_2, \uparrow \nabla, 11 \uparrow \nabla, 111111 \uparrow \nabla)$$

11.



$$K_{10} = (q_3, \uparrow \nabla, 1 \uparrow 1, 111111 \uparrow \nabla)$$

12.



$$K_{11} = (q_5, \uparrow \nabla, 1 \uparrow 1, 111111 \uparrow 1)$$

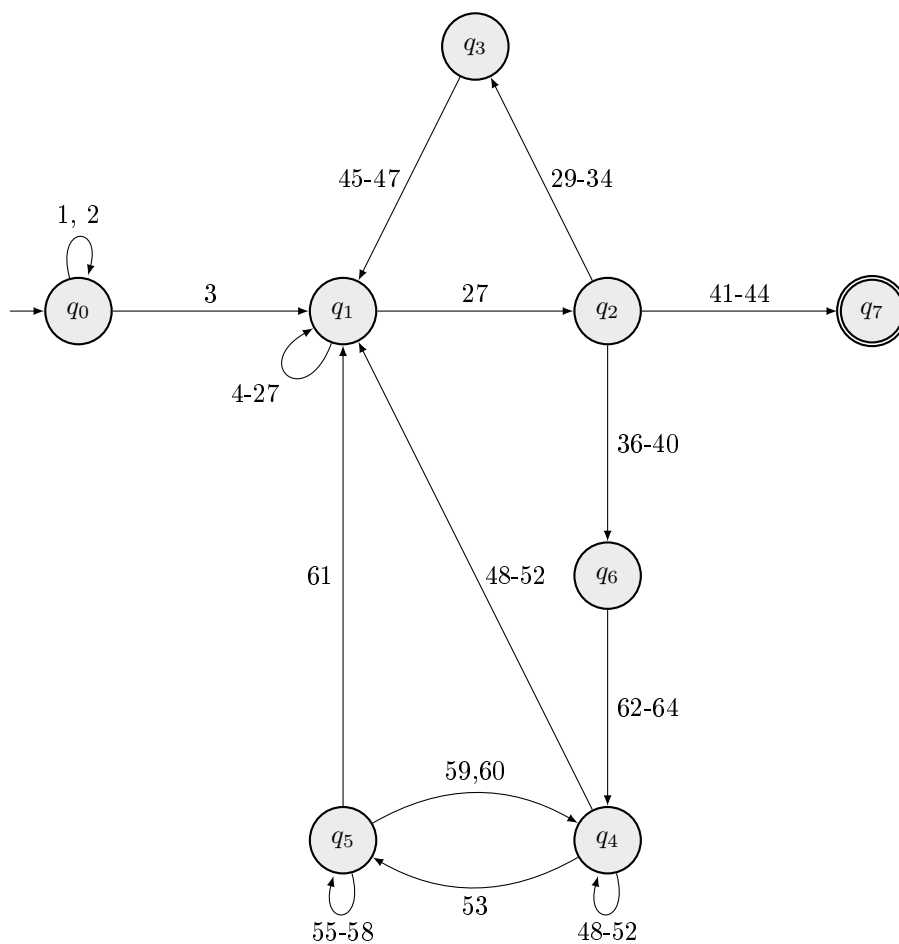
5.4 Zadanie 1.57

Używając binarnej reprezentacji liczb, zaprojektuj wielotaśmową maszynę Turinga, która oblicza funkcję

$$(46) \quad f(n) = n^2$$

Podaj tabelę przejść i narysuj diagram przejść. Dla zaprojektowanej maszyny wykonaj dwa obliczenia (wykonaj rysunki taśm i zapisz konfiguracje).

$$(47) \quad M = (Q, \Sigma, \Gamma, \delta, q_0, \nabla, F) = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6, q_7\}, \{1, 0\}, \{1, 0, \nabla\}, \delta, q_0, \nabla, \{q_7\})$$



Nr	Stan bieżący	Czytany symbol	Nowy symbol	Nowy stan	Kierunki głowic
1	q_0	$[0, \nabla, \nabla]$	$[0, 0, \nabla]$	q_0	$[\rightarrow, \rightarrow, \rightarrow]$
2	q_0	$[1, \nabla, \nabla]$	$[1, 1, \nabla]$	q_0	$[\rightarrow, \rightarrow, \rightarrow]$
3	q_0	$[\nabla, \nabla, \nabla]$	$[\nabla, \nabla, \nabla]$	q_2	$[\leftarrow, \leftarrow, \leftarrow]$

Tabela 1: Tabela przejścia dla stanu q_0

Nr	Stan bieżący	Czytany symbol	Nowy symbol	Nowy stan	Kierunki głowic
4	q_1	[0, 0, 0]	[0, 0, 0]	q_1	[→, →, →]
5	q_1	[0, 0, 1]	[0, 0, 1]	q_1	[→, →, →]
6	q_1	[0, 1, 0]	[0, 1, 0]	q_1	[→, →, →]
7	q_1	[0, 1, 1]	[0, 1, 1]	q_1	[→, →, →]
8	q_1	[1, 0, 0]	[1, 0, 0]	q_1	[→, →, →]
9	q_1	[1, 0, 1]	[1, 0, 1]	q_1	[→, →, →]
10	q_1	[1, 1, 0]	[1, 1, 0]	q_1	[→, →, →]
11	q_1	[1, 1, 1]	[1, 1, 1]	q_1	[→, →, →]
12	q_1	[∇, 0, 0]	[∇, 0, 0]	q_1	[←, →, →]
13	q_1	[∇, 0, 1]	[∇, 0, 1]	q_1	[←, →, →]
14	q_1	[∇, 1, 0]	[∇, 1, 0]	q_1	[←, →, →]
15	q_1	[∇, 1, 1]	[∇, 1, 1]	q_1	[←, →, →]
16	q_1	[0, ∇, 0]	[0, ∇, 0]	q_1	[→, ←, →]
17	q_1	[0, ∇, 1]	[0, ∇, 1]	q_1	[→, ←, →]
18	q_1	[1, ∇, 0]	[1, ∇, 0]	q_1	[→, ←, →]
19	q_1	[1, ∇, 1]	[1, ∇, 1]	q_1	[→, ←, →]
20	q_1	[0, 0, ∇]	[0, 0, ∇]	q_1	[→, →, ←]
21	q_1	[0, 1, ∇]	[0, 1, ∇]	q_1	[→, →, ←]
22	q_1	[1, 0, ∇]	[1, 0, ∇]	q_1	[→, →, ←]
23	q_1	[1, 1, ∇]	[1, 1, ∇]	q_1	[→, →, ←]
24	q_1	[∇, ∇, 0]	[∇, ∇, 0]	q_1	[←, ←, →]
25	q_1	[∇, ∇, 1]	[∇, ∇, 1]	q_1	[←, ←, →]
26	q_1	[0, ∇, ∇]	[0, ∇, ∇]	q_1	[→, ←, ←]
27	q_1	[1, ∇, ∇]	[1, ∇, ∇]	q_1	[→, ←, ←]
28	q_1	[∇, ∇, ∇]	[∇, ∇, ∇]	q_2	[←, ←, ←]

Tabela 2: Tabela przejścia dla bieżącego stanu q_1

Nr	Stan bieżący	Czytany symbol	Nowy symbol	Nowy stan	Kierunki głowic
29	q_2	[1, 0, ∇]	[1, ∇ , ∇]	q_3	[\rightarrow , $-$, $-$]
30	q_2	[0, 0, ∇]	[0, ∇ , ∇]	q_3	[\rightarrow , $-$, $-$]
31	q_2	[1, 0, 1]	[1, ∇ , 1]	q_3	[\rightarrow , $-$, $-$]
32	q_2	[1, 0, 0]	[1, ∇ , 0]	q_3	[\rightarrow , $-$, $-$]
33	q_2	[0, 0, 1]	[0, ∇ , 1]	q_3	[\rightarrow , $-$, $-$]
34	q_2	[0, 0, 0]	[0, ∇ , 0]	q_3	[\rightarrow , $-$, $-$]
35	q_2	[1, 1, ∇]	[1, ∇ , ∇]	q_6	[\rightarrow , $-$, $-$]
36	q_2	[0, 1, ∇]	[0, ∇ , ∇]	q_6	[\rightarrow , $-$, $-$]
37	q_2	[1, 1, 1]	[1, ∇ , 1]	q_6	[\rightarrow , $-$, $-$]
38	q_2	[1, 1, 0]	[1, ∇ , 0]	q_6	[\rightarrow , $-$, $-$]
39	q_2	[0, 1, 1]	[0, ∇ , 1]	q_6	[\rightarrow , $-$, $-$]
40	q_2	[0, 1, 0]	[0, ∇ , 0]	q_6	[\rightarrow , $-$, $-$]
41	q_2	[0, ∇ , 0]	[0, ∇ , 0]	q_7	[$-$, $-$, $-$]
42	q_2	[0, ∇ , 1]	[0, ∇ , 1]	q_7	[$-$, $-$, $-$]
43	q_2	[1, ∇ , 0]	[1, ∇ , 0]	q_7	[$-$, $-$, $-$]
44	q_2	[1, ∇ , 1]	[1, ∇ , 1]	q_7	[$-$, $-$, $-$]

Tabela 3: Tabela przejścia dla bieżącego stanu q_2

Nr	Stan bieżący	Czytany symbol	Nowy symbol	Nowy stan	Kierunki głowic
45	q_3	[∇ , ∇ , ∇]	[∇ , ∇ , 0]	q_1	[\leftarrow , $-$, $-$]
46	q_3	[∇ , ∇ , 1]	[0, ∇ , 1]	q_1	[\rightarrow , $-$, $-$]
47	q_3	[∇ , ∇ , 0]	[0, ∇ , 0]	q_1	[\rightarrow , $-$, $-$]

Tabela 4: Tabela przejścia dla bieżącego stanu q_3

Nr	Stan bieżący	Czytany symbol	Nowy symbol	Nowy stan	Kierunki głowic
48	q_4	[1, ∇ , ∇]	[1, ∇ , 1]	q_4	[\leftarrow , $-$, \leftarrow]
49	q_4	[1, ∇ , 0]	[1, ∇ , 1]	q_4	[\leftarrow , $-$, \leftarrow]
50	q_4	[0, ∇ , 1]	[0, ∇ , 1]	q_4	[\leftarrow , $-$, \leftarrow]
51	q_4	[0, ∇ , ∇]	[0, ∇ , 0]	q_4	[\leftarrow , $-$, \leftarrow]
52	q_4	[0, ∇ , 0]	[0, ∇ , 0]	q_4	[\leftarrow , $-$, \leftarrow]
53	q_4	[1, ∇ , 1]	[1, ∇ , 0]	q_5	[\leftarrow , $-$, \leftarrow]
54	q_4	[∇ , ∇ , ∇]	[∇ , ∇ , ∇]	q_1	[\rightarrow , $-$, \rightarrow]

Tabela 5: Tabela przejścia dla bieżącego stanu q_4

Nr	Stan bieżący	Czytany symbol	Nowy symbol	Nowy stan	Kierunki głowic
55	q_5	$[1, \nabla, 1]$	$[1, \nabla, 1]$	q_5	$[\leftarrow, \text{—}, \leftarrow]$
56	q_5	$[0, \nabla, 1]$	$[0, \nabla, 0]$	q_5	$[\leftarrow, \text{—}, \leftarrow]$
57	q_5	$[1, \nabla, 0]$	$[1, \nabla, 0]$	q_5	$[\leftarrow, \text{—}, \leftarrow]$
58	q_5	$[1, \nabla, \nabla]$	$[1, \nabla, 0]$	q_5	$[\leftarrow, \text{—}, \leftarrow]$
59	q_5	$[0, \nabla, 0]$	$[0, \nabla, 1]$	q_4	$[\leftarrow, \text{—}, \leftarrow]$
60	q_5	$[0, \nabla, \nabla]$	$[0, \nabla, 1]$	q_4	$[\leftarrow, \text{—}, \leftarrow]$
61	q_5	$[\nabla, \nabla, \nabla]$	$[\nabla, \nabla, 1]$	q_1	$[\rightarrow, \text{—}, \rightarrow]$

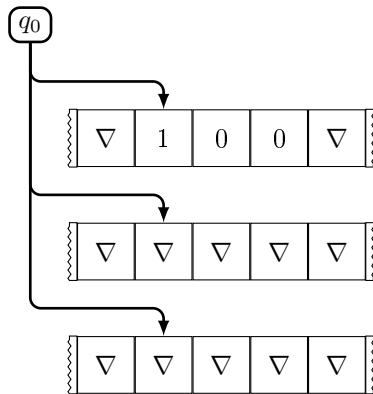
Tabela 6: Tabela przejścia dla bieżącego stanu q_5

Nr	Stan bieżący	Czytany symbol	Nowy symbol	Nowy stan	Kierunki głowic
62	q_6	$[\nabla, \nabla, \nabla]$	$[\nabla, \nabla, \nabla]$	q_4	$[\leftarrow, \text{—}, \text{—}]$
63	q_6	$[\nabla, \nabla, 1]$	$[0, \nabla, 1]$	q_4	$[\text{—}, \text{—}, \text{—}]$
64	q_6	$[\nabla, \nabla, 0]$	$[0, \nabla, 0]$	q_4	$[\text{—}, \text{—}, \text{—}]$

Tabela 7: Tabela przejścia dla bieżącego stanu q_6

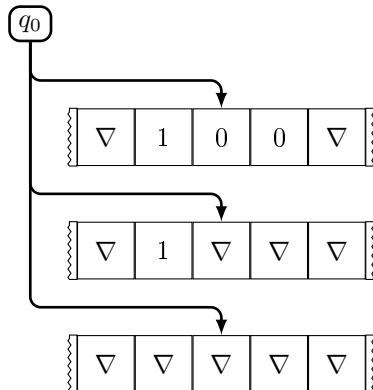
5.4.1 f(4)

1.



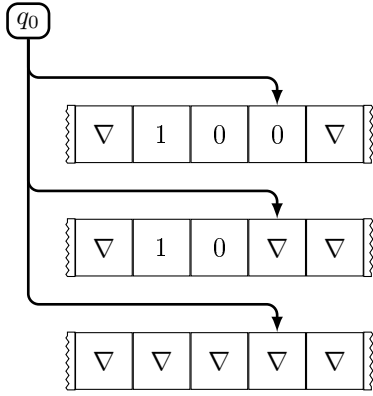
$$K_0 = (q_0, \uparrow 100, \uparrow \nabla, \uparrow \nabla)$$

2.



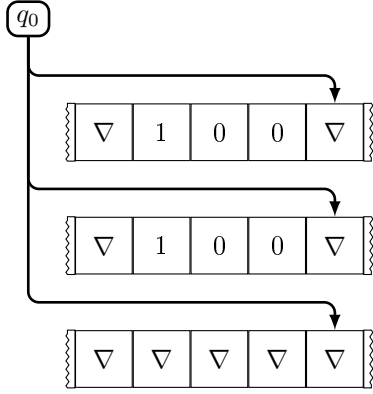
$$K_1 = (q_0, 1\uparrow 00, 1\uparrow \nabla, \uparrow \nabla)$$

3.



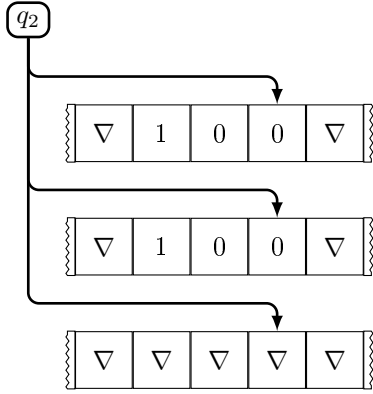
$$K_2 = (q_0, 10\uparrow 0, 10\uparrow \nabla, \uparrow \nabla)$$

4.



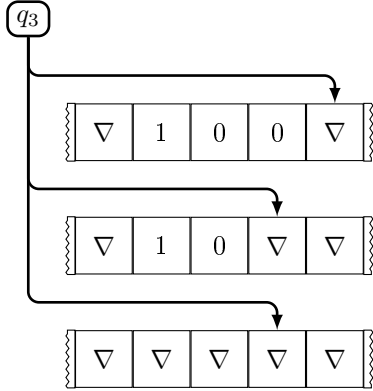
$$K_3 = (q_0, 100\uparrow \nabla, 100\uparrow \nabla, \uparrow \nabla)$$

5.



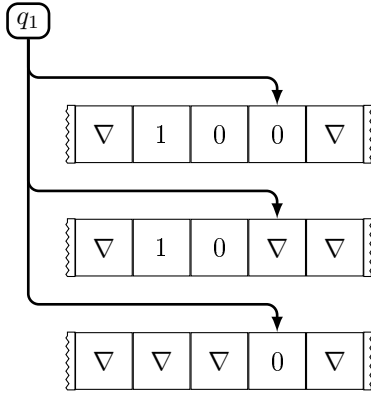
$$K_4 = (q_2, 10\uparrow 0, 10\uparrow 0, \uparrow \nabla)$$

6.



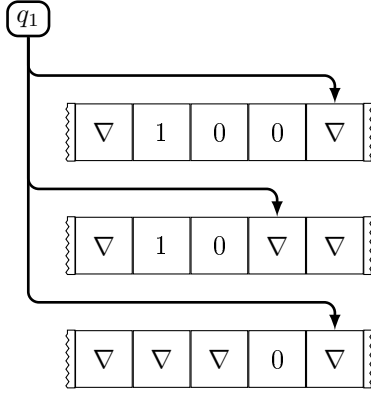
$$K_5 = (q_3, 100\uparrow \nabla, 10\uparrow \nabla, \uparrow \nabla)$$

7.



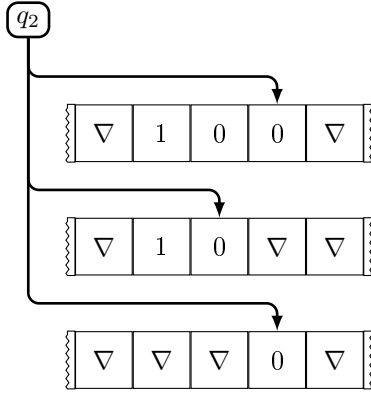
$$K_6 = (q_1, 10\uparrow 0, 10\uparrow \nabla, \uparrow 0)$$

8.



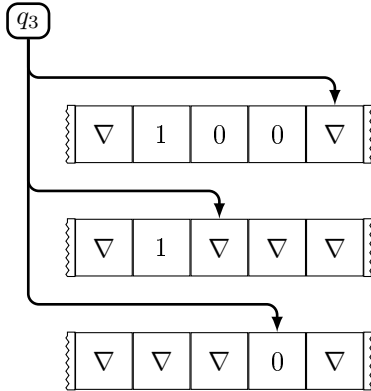
$$K_7 = (q_1, 100\uparrow \nabla, 10\uparrow \nabla, 0\uparrow \nabla)$$

9.



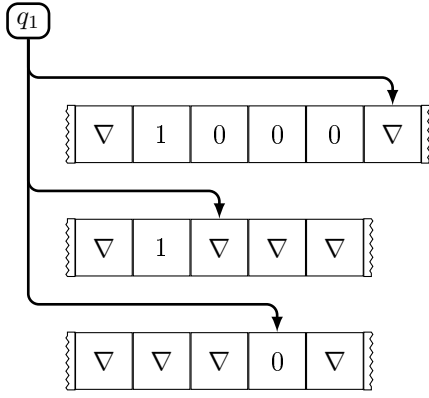
$$K_8 = (q_2, 10\uparrow 0, 1\uparrow 0, \uparrow 0)$$

10.



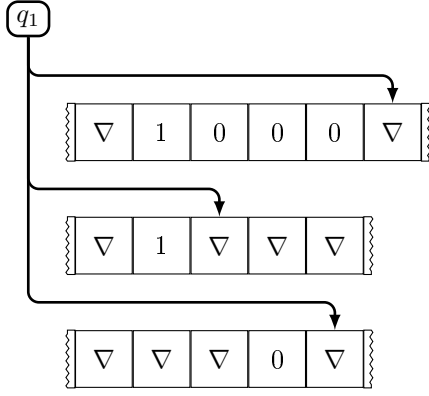
$$K_9 = (q_3, 100\uparrow \nabla, 1\uparrow \nabla, \uparrow 0)$$

11.



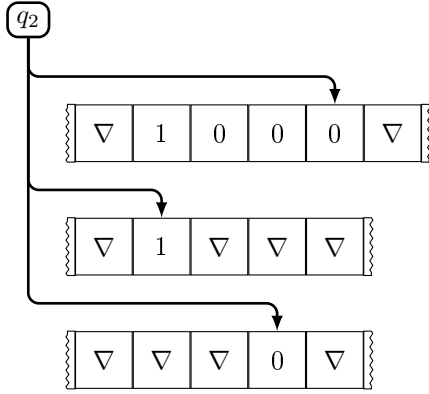
$$K_{10} = (q_1, 1000\uparrow\nabla, 1\uparrow\nabla, \uparrow 0)$$

12.



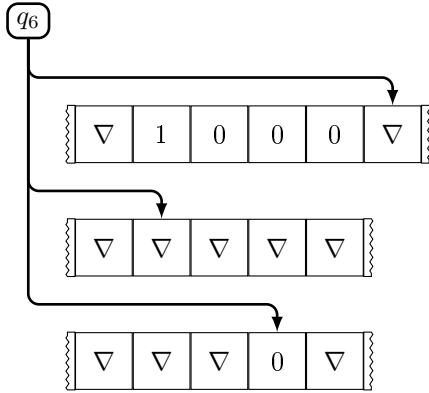
$$K_{11} = (q_1, 1000\uparrow\nabla, 1\uparrow\nabla, 0\uparrow\nabla)$$

13.



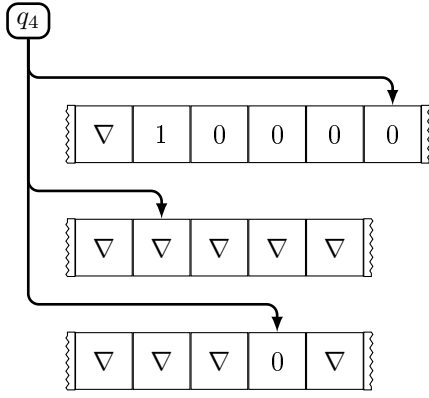
$$K_{12} = (q_2, 100\uparrow 0, \uparrow 1, \uparrow 0)$$

14.



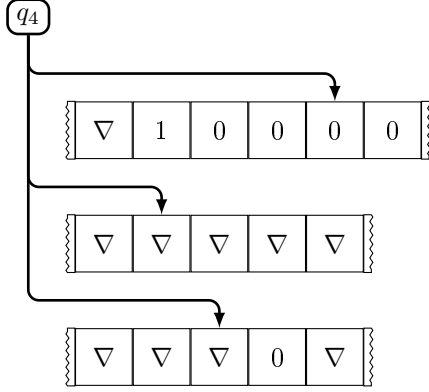
$$K_{13} = (q_6, 1000\uparrow\nabla, \uparrow\nabla, \uparrow 0)$$

15.



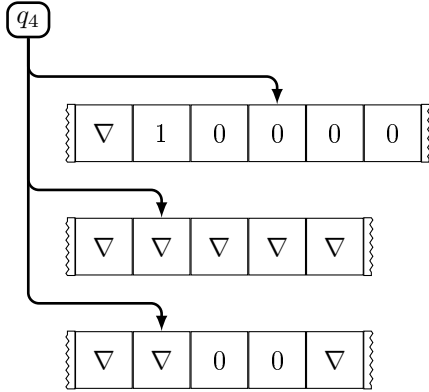
$$K_{14} = (q_4, 1000\uparrow 0, \uparrow \nabla, \uparrow 0)$$

16.



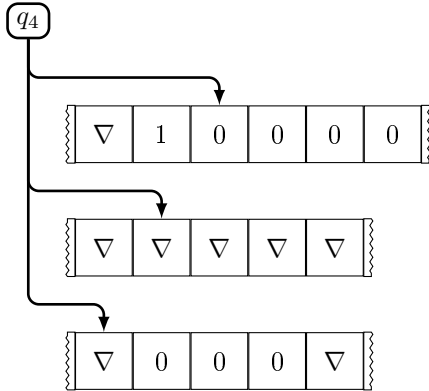
$$K_{15} = (q_4, 100\uparrow 00, \uparrow \nabla, \uparrow \nabla 0)$$

17.



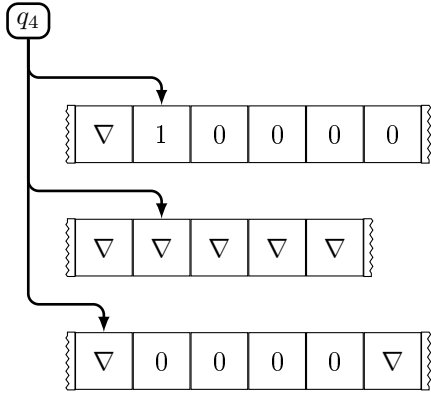
$$K_{16} = (q_4, 10\uparrow 000, \uparrow \nabla, \uparrow \nabla 00)$$

18.



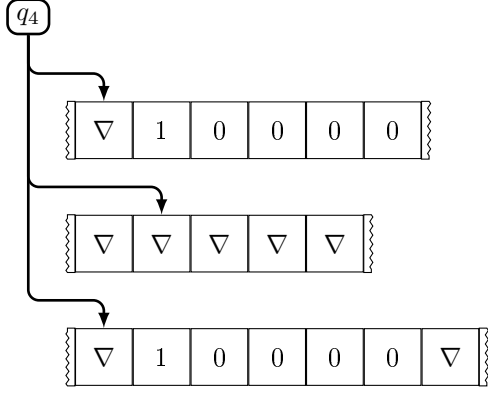
$$K_{17} = (q_4, 1\uparrow 0000, \uparrow \nabla, \uparrow \nabla 000)$$

19.



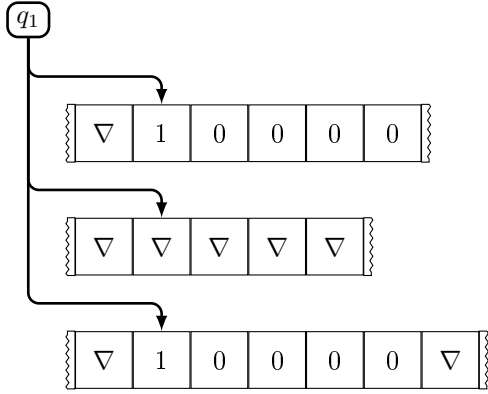
$$K_{18} = (q_4, \uparrow 10000, \uparrow \nabla, \uparrow \nabla 0000)$$

20.



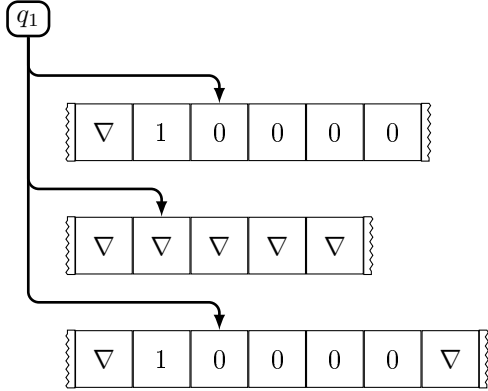
$$K_{19} = (q_4, \uparrow \nabla 10000, \uparrow \nabla, \uparrow \nabla 10000)$$

21.



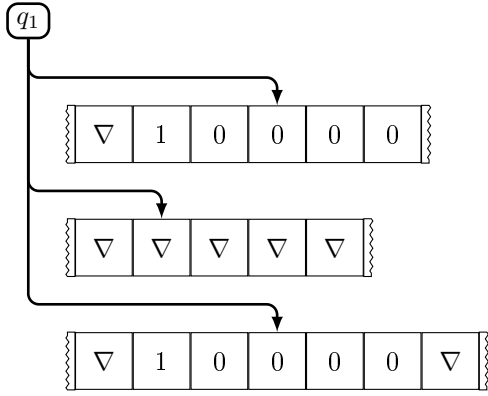
$$K_{20} = (q_1, \uparrow 10000, \uparrow \nabla, \uparrow 10000)$$

22.



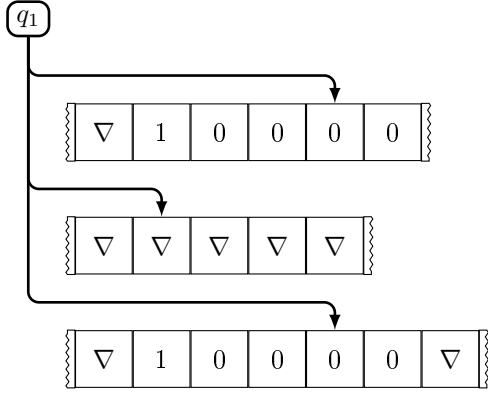
$$K_{21} = (q_1, 1\uparrow 0000, \uparrow \nabla, 1\uparrow 0000)$$

23.



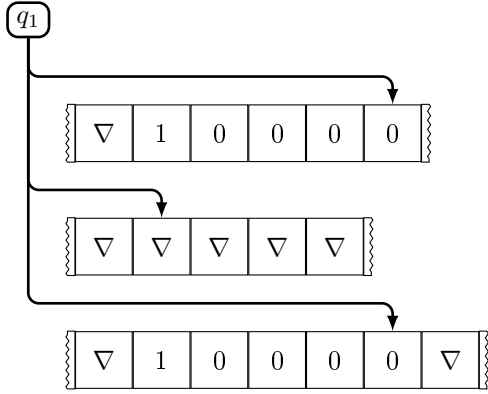
$$K_{22} = (q_1, 10\uparrow 000, \uparrow \nabla, 10\uparrow 000)$$

24.



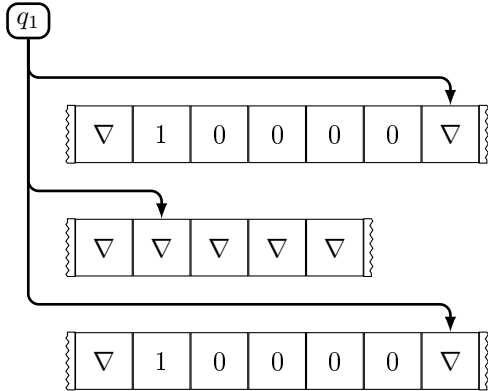
$$K_{23} = (q_1, 100\uparrow 00, \uparrow \nabla, 100\uparrow 00)$$

25.



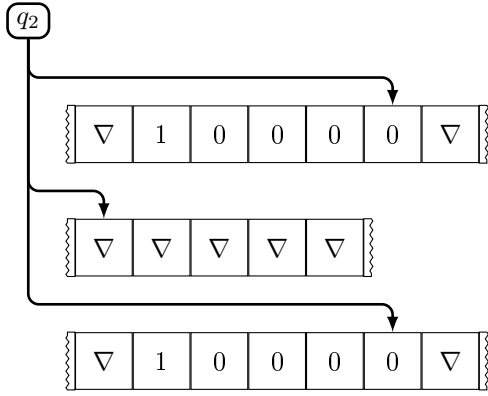
$$K_{24} = (q_1, 1000\uparrow 0, \uparrow \nabla, 1000\uparrow 0)$$

26.



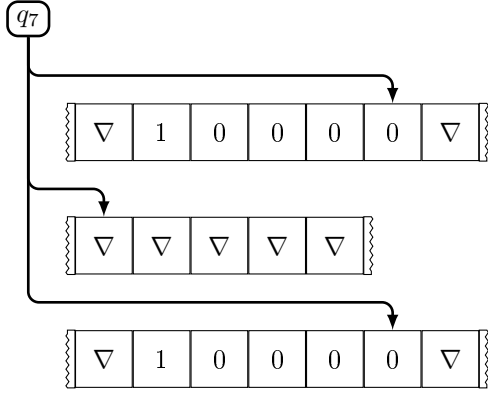
$$K_{25} = (q_1, 10000\uparrow \nabla, \uparrow \nabla, 10000\uparrow \nabla)$$

27.



$$K_{26} = (q_2, 1000\uparrow 0, \uparrow \nabla, 1000\uparrow 0)$$

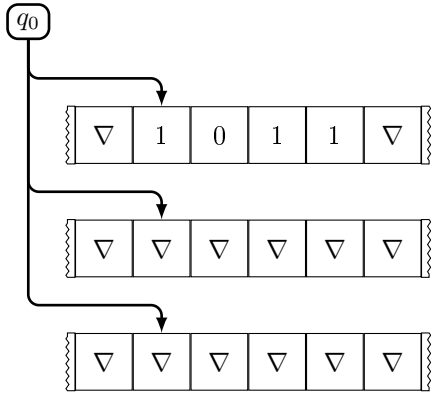
28.



$$K_{27} = (q_7, 1000\uparrow 0, \uparrow \nabla, 1000\uparrow 0)$$

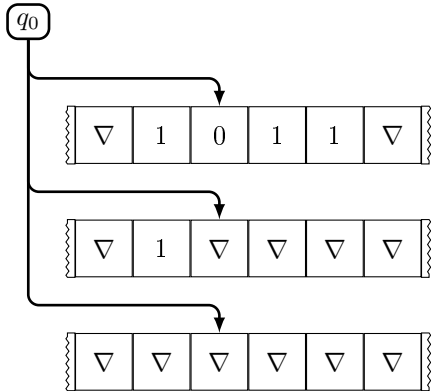
5.4.2 f(11)

1.



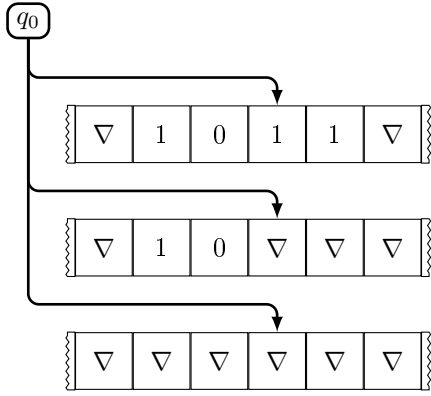
$$K_0 = (q_0, \uparrow 1011, \uparrow \nabla, \uparrow \nabla)$$

2.



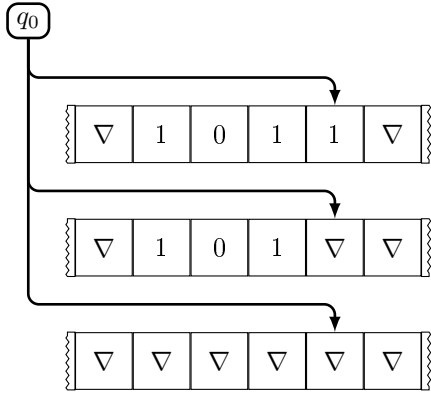
$$K_1 = (q_0, 1\uparrow 011, 1\uparrow \nabla, \uparrow \nabla)$$

3.



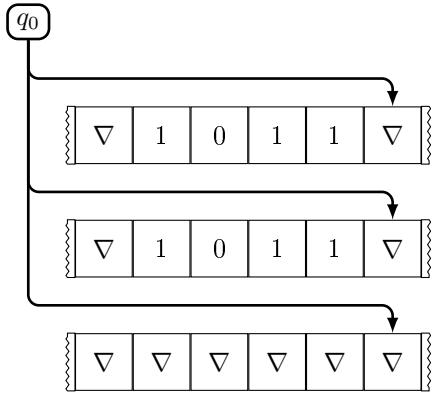
$$K_2 = (q_0, 10\uparrow 11, 10\uparrow \nabla, \uparrow \nabla)$$

4.



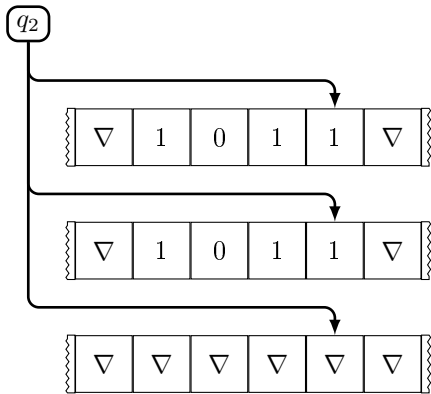
$$K_3 = (q_0, 101\uparrow 1, 101\uparrow \nabla, \uparrow \nabla)$$

5.



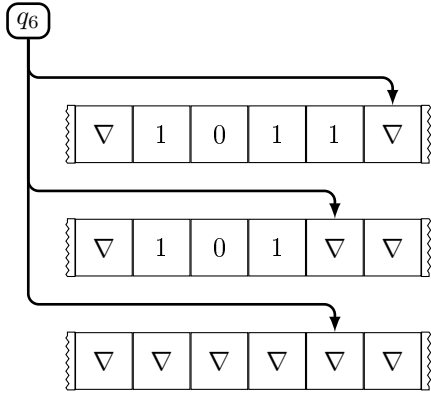
$$K_4 = (q_0, 1011\uparrow \nabla, 1011\uparrow \nabla, \uparrow \nabla)$$

6.



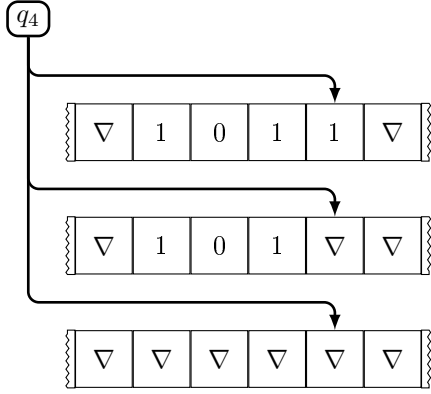
$$K_5 = (q_2, 101\uparrow 1, 101\uparrow 1, \uparrow \nabla)$$

7.



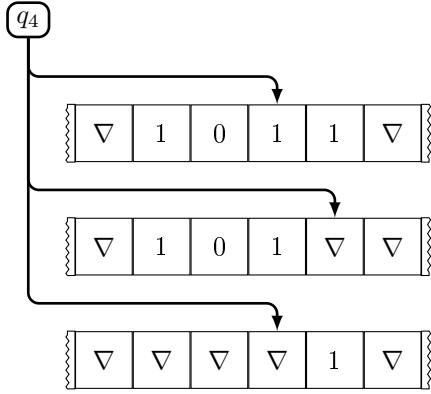
$$K_6 = (q_6, 1011\uparrow\nabla, 101\uparrow\nabla, \uparrow\nabla)$$

8.



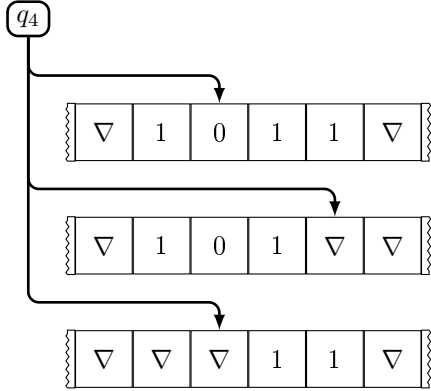
$$K_7 = (q_4, 101\uparrow 1, 101\uparrow\nabla, \uparrow\nabla)$$

9.



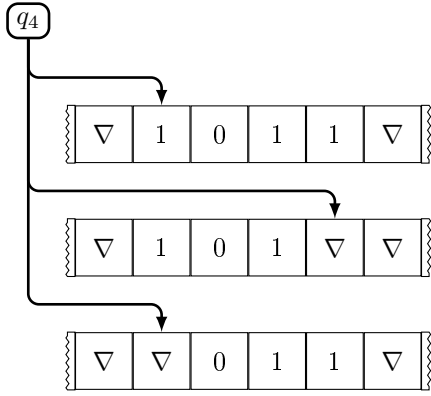
$$K_8 = (q_4, 10\uparrow 11, 101\uparrow\nabla, \uparrow\nabla 1)$$

10.



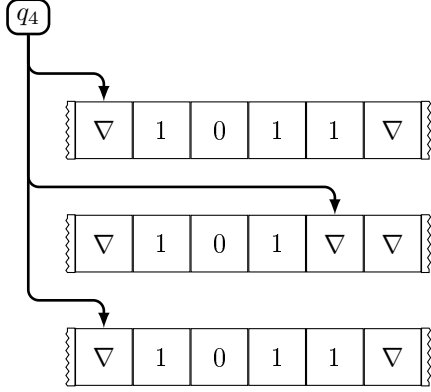
$$K_9 = (q_4, 1\uparrow 011, 101\uparrow\nabla, \uparrow\nabla 11)$$

11.



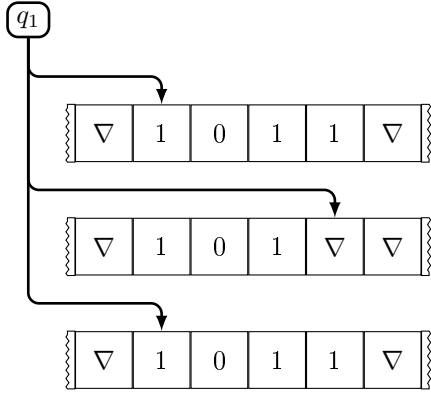
$$K_{10} = (q_4, \uparrow 1011, 101\uparrow\nabla, \uparrow\nabla 011)$$

12.



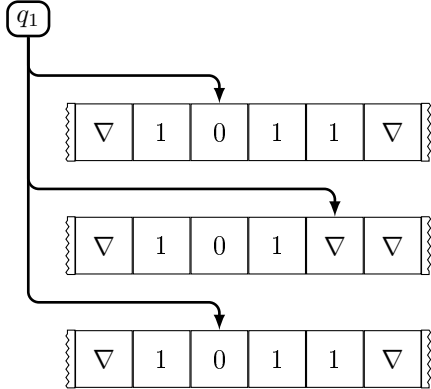
$$K_{11} = (q_4, \uparrow\nabla 1011, 101\uparrow\nabla, \uparrow\nabla 1011)$$

13.



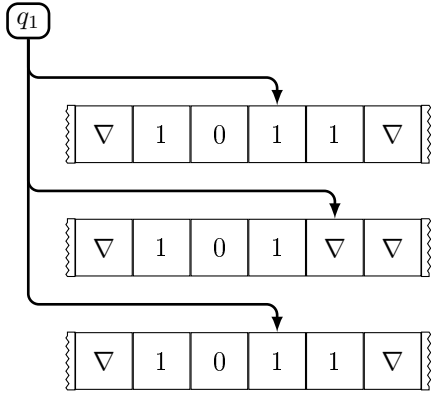
$$K_{12} = (q_1, \uparrow 1011, 101\uparrow\nabla, \uparrow 1011)$$

14.



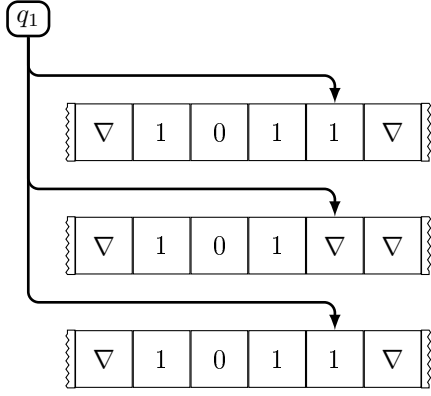
$$K_{13} = (q_1, 1\uparrow 011, 101\uparrow\nabla, 1\uparrow 011)$$

15.



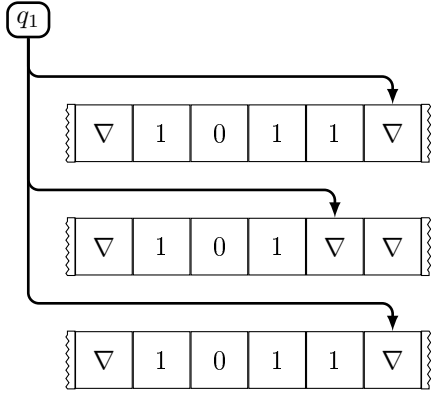
$$K_{14} = (q_1, 10\uparrow 11, 101\uparrow \nabla, 10\uparrow 11)$$

16.



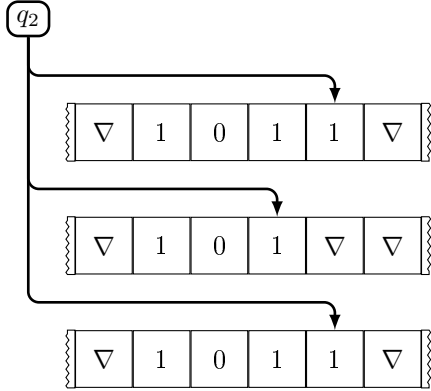
$$K_{15} = (q_1, 101\uparrow 1, 101\uparrow \nabla, 101\uparrow 1)$$

17.



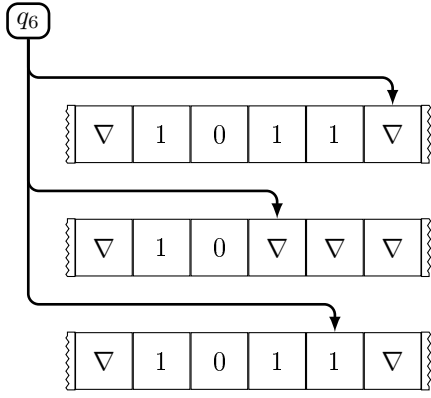
$$K_{16} = (q_1, 1011\uparrow \nabla, 101\uparrow \nabla, 1011\uparrow \nabla)$$

18.



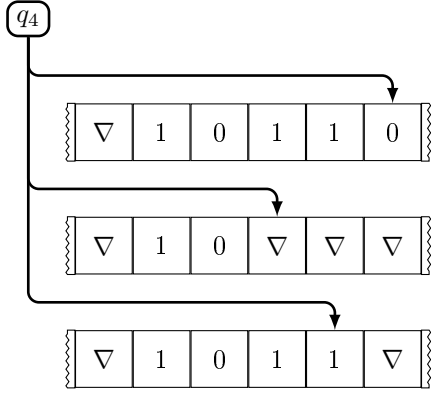
$$K_{17} = (q_2, 101\uparrow 1, 10\uparrow 1, 101\uparrow 1)$$

19.



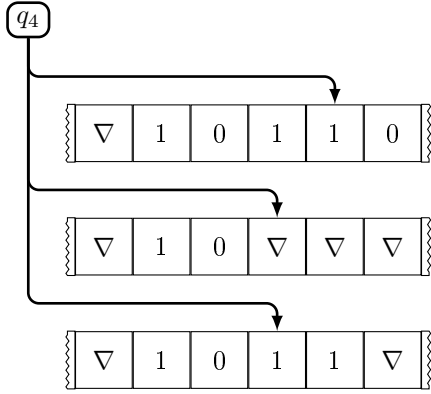
$$K_{18} = (q_6, 1011\uparrow\nabla, 10\uparrow\nabla, 101\uparrow 1)$$

20.



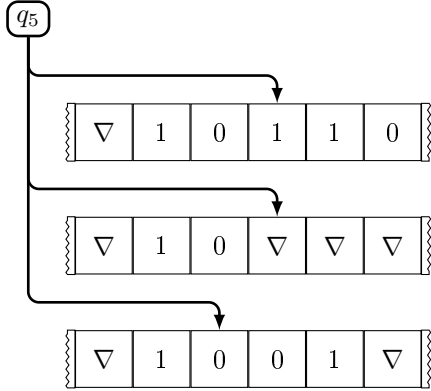
$$K_{19} = (q_4, 1011\uparrow 0, 10\uparrow\nabla, 101\uparrow 1)$$

21.



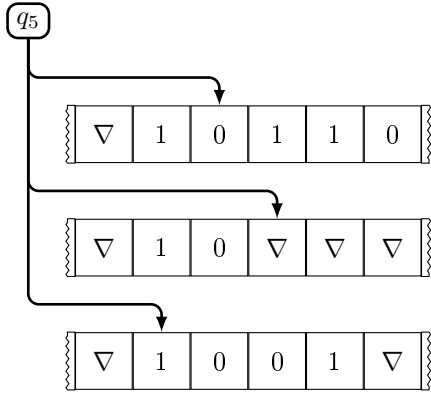
$$K_{20} = (q_4, 101\uparrow 10, 10\uparrow\nabla, 10\uparrow 11)$$

22.



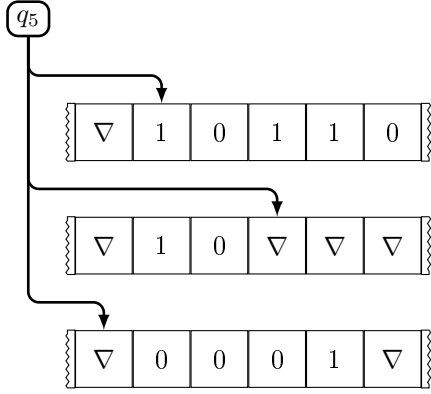
$$K_{21} = (q_5, 10\uparrow 110, 10\uparrow\nabla, 1\uparrow 001)$$

23.



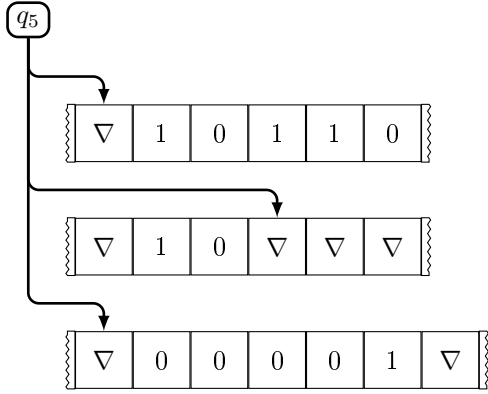
$$K_{22} = (q_5, 1\uparrow 0110, 10\uparrow \nabla, \uparrow 1001)$$

24.



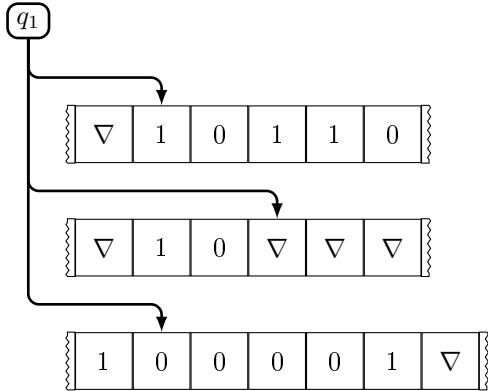
$$K_{23} = (q_5, \uparrow 10110, 10\uparrow \nabla, \uparrow \nabla 0001)$$

25.



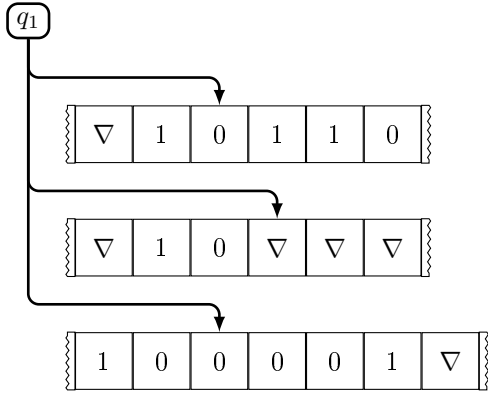
$$K_{24} = (q_5, \uparrow \nabla 10110, 10\uparrow \nabla, \uparrow \nabla 00001)$$

26.



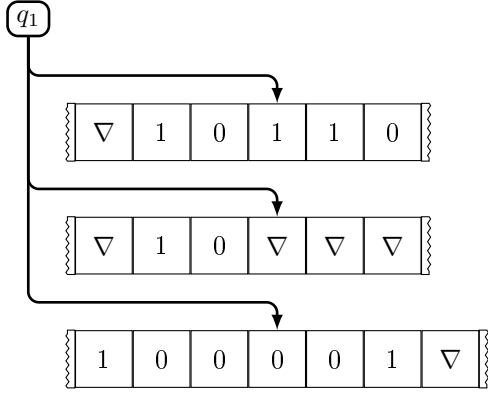
$$K_{25} = (q_1, \uparrow 10110, 10\uparrow \nabla, 1\uparrow 00001)$$

27.



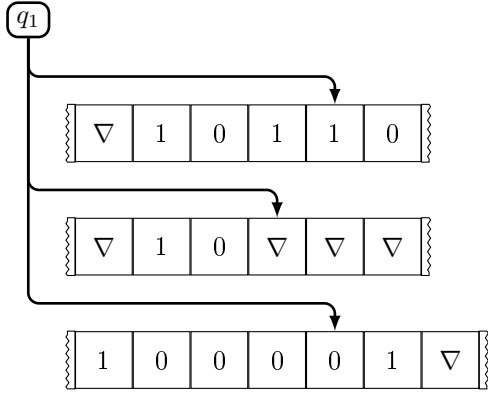
$$K_{26} = (q_1, 1\uparrow 0110, 10\uparrow \nabla, 10\uparrow 0001)$$

28.



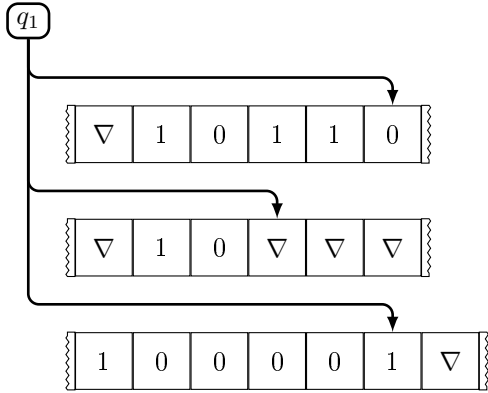
$$K_{27} = (q_1, 10\uparrow 110, 10\uparrow \nabla, 100\uparrow 001)$$

29.



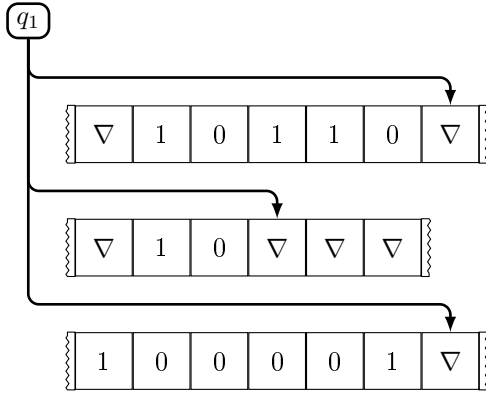
$$K_{28} = (q_1, 101\uparrow 10, 10\uparrow \nabla, 1000\uparrow 01)$$

30.



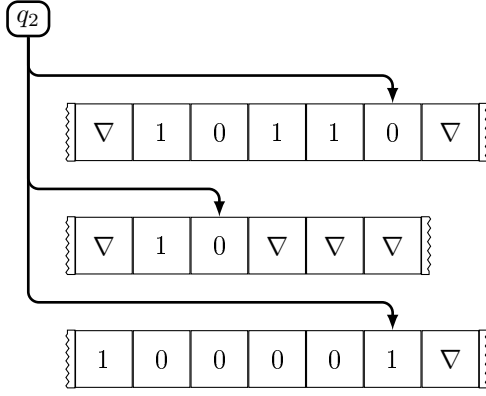
$$K_{29} = (q_1, 1011\uparrow 0, 10\uparrow \nabla, 10000\uparrow 1)$$

31.



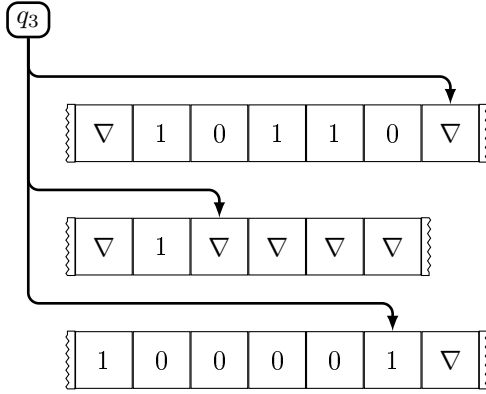
$$K_{30} = (q_1, 10110\uparrow\nabla, 10\uparrow\nabla, 100001\uparrow\nabla)$$

32.



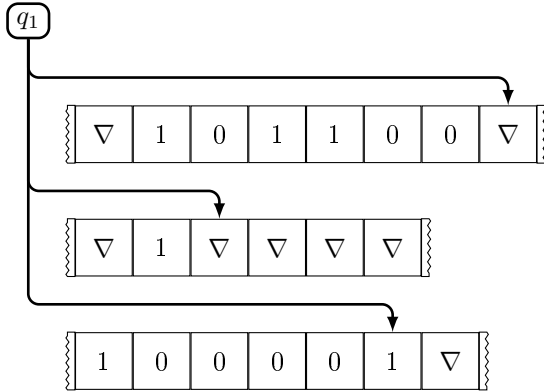
$$K_{31} = (q_2, 1011\uparrow 0, 1\uparrow 0, 10000\uparrow 1)$$

33.



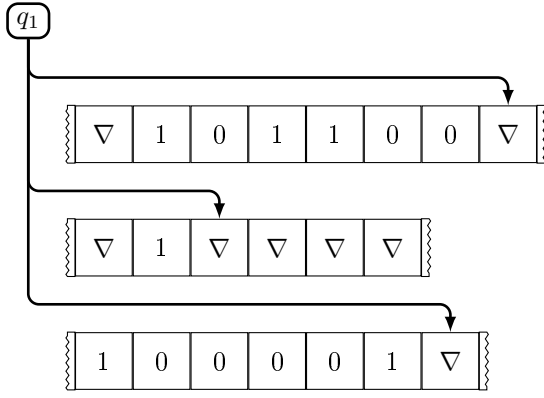
$$K_{32} = (q_3, 10110\uparrow\nabla, 1\uparrow\nabla, 10000\uparrow 1)$$

34.



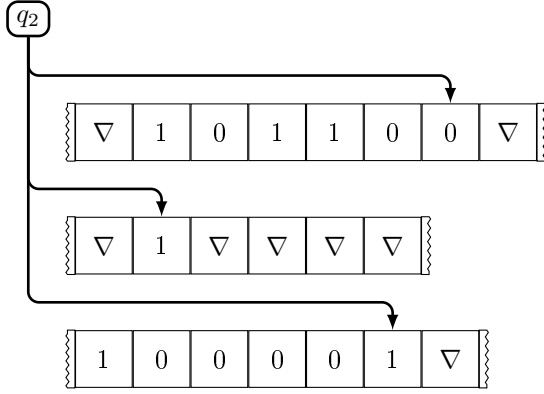
$$K_{33} = (q_1, 101100\uparrow\nabla, 1\uparrow\nabla, 10000\uparrow 1)$$

35.



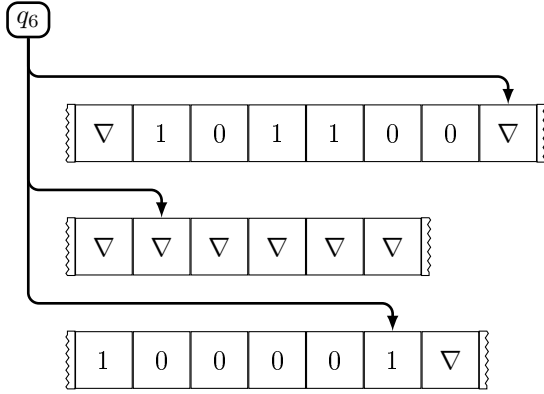
$$K_{34} = (q_1, 101100\uparrow\nabla, 1\uparrow\nabla, 100001\uparrow\nabla)$$

36.



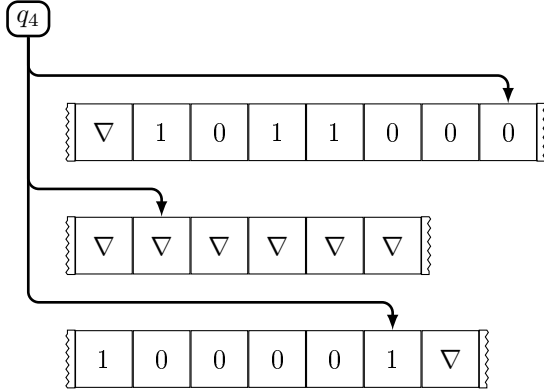
$$K_{35} = (q_2, 10110\uparrow 0, \uparrow 1, 10000\uparrow 1)$$

37.



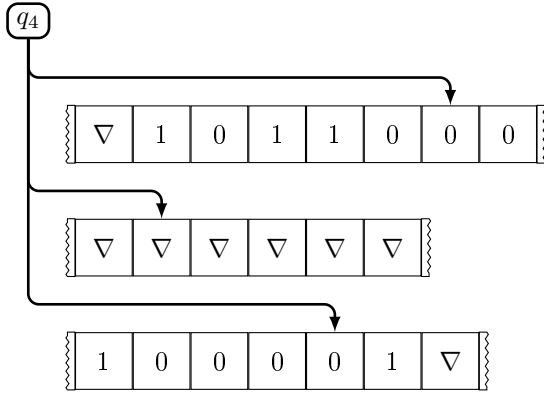
$$K_{36} = (q_6, 101100\uparrow\nabla, \uparrow\nabla, 10000\uparrow 1)$$

38.



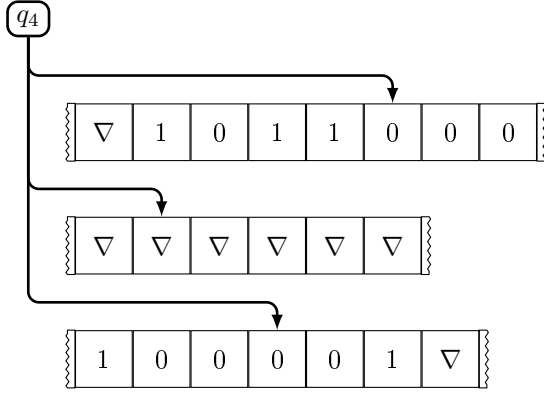
$$K_{37} = (q_4, 101100\uparrow 0, \uparrow\nabla, 10000\uparrow 1)$$

39.



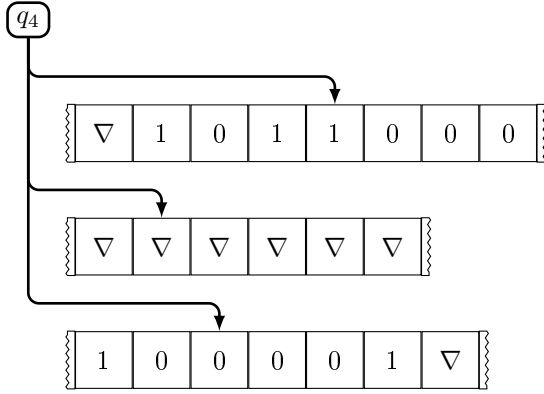
$$K_{38} = (q_4, 10110\uparrow 00, \uparrow \nabla, 1000\uparrow 01)$$

40.



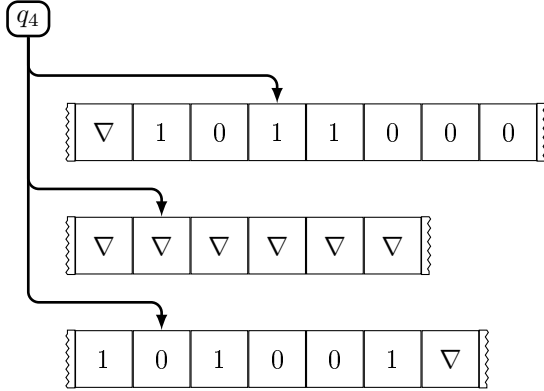
$$K_{39} = (q_4, 1011\uparrow 000, \uparrow \nabla, 100\uparrow 001)$$

41.



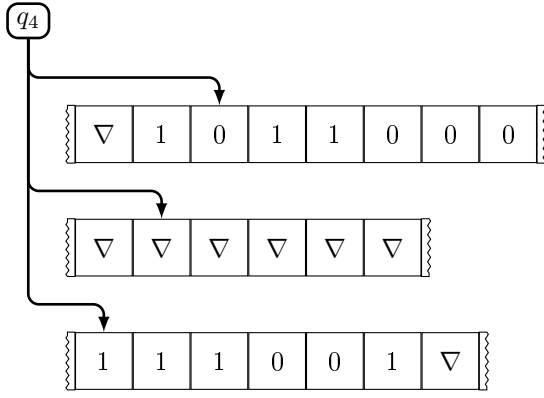
$$K_{40} = (q_4, 101\uparrow 1000, \uparrow \nabla, 10\uparrow 0001)$$

42.



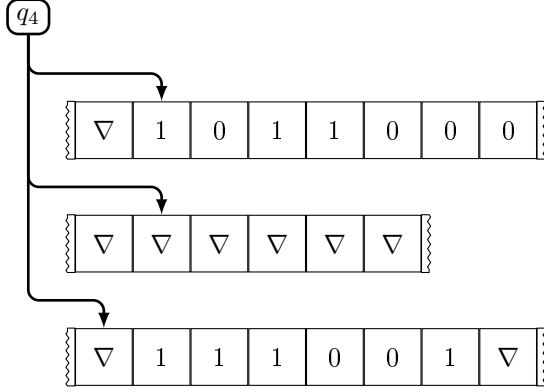
$$K_{41} = (q_4, 10\uparrow 11000, \uparrow \nabla, 1\uparrow 01001)$$

43.



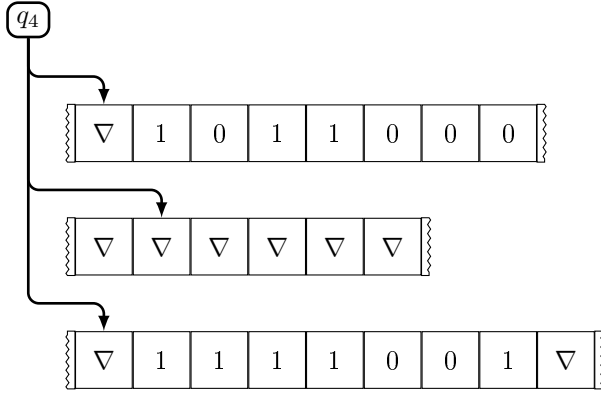
$$K_{42} = (q_4, 1\uparrow 011000, \uparrow \nabla, \uparrow 111001)$$

44.



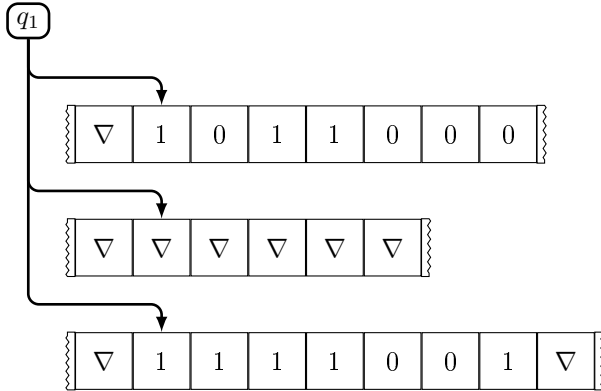
$$K_{43} = (q_4, \uparrow 1011000, \uparrow \nabla, \uparrow \nabla 111001)$$

45.



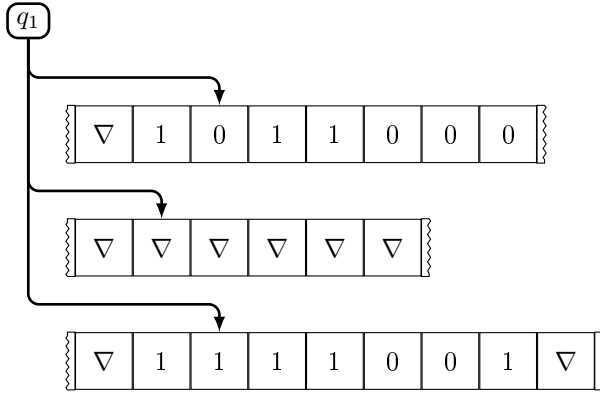
$$K_{44} = (q_4, \uparrow \nabla 1011000, \uparrow \nabla, \uparrow \nabla 1111001)$$

46.



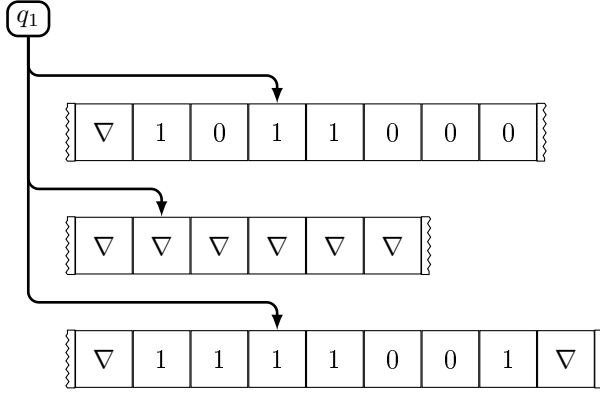
$$K_{45} = (q_1, \uparrow 1011000, \uparrow \nabla, \uparrow 1111001)$$

47.



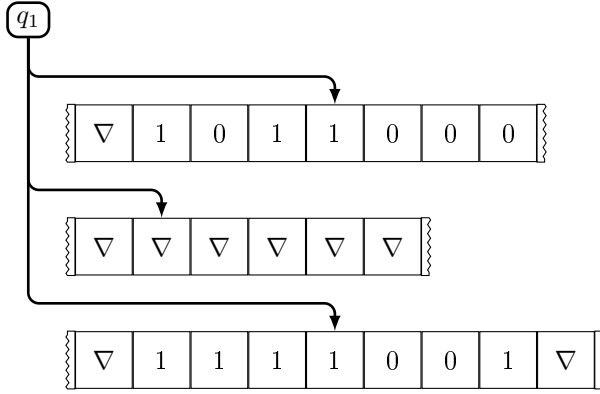
$$K_{46} = (q_1, 1\uparrow 011000, \uparrow \nabla, 1\uparrow 111001)$$

48.



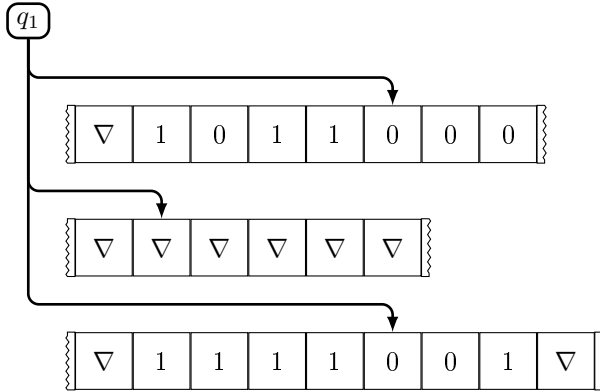
$$K_{47} = (q_1, 10\uparrow 11000, \uparrow \nabla, 11\uparrow 11001)$$

49.



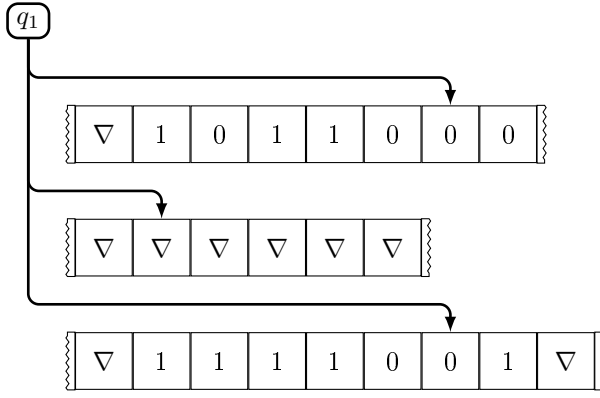
$$K_{48} = (q_1, 101\uparrow 1000, \uparrow \nabla, 111\uparrow 1001)$$

50.



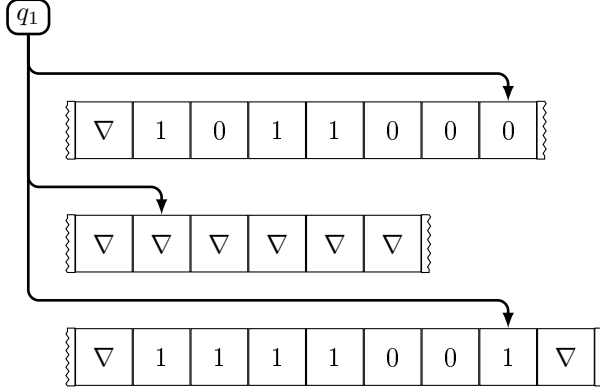
$$K_{49} = (q_1, 1011\uparrow 000, \uparrow \nabla, 1111\uparrow 001)$$

51.



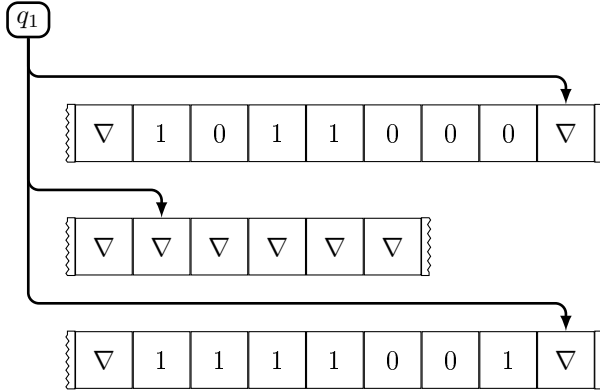
$$K_{50} = (q_1, 10110\uparrow 00, \uparrow \nabla, 11110\uparrow 01)$$

52.



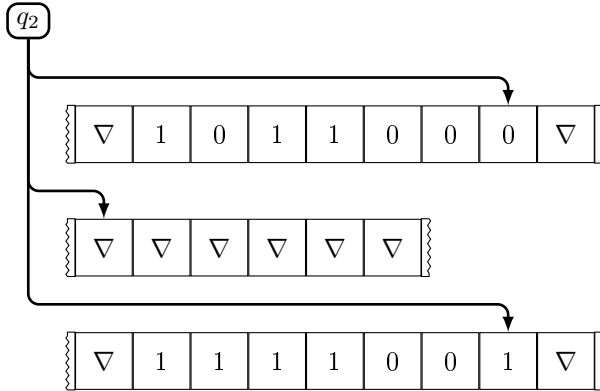
$$K_{51} = (q_1, 101100\uparrow 0, \uparrow \nabla, 111100\uparrow 1)$$

53.



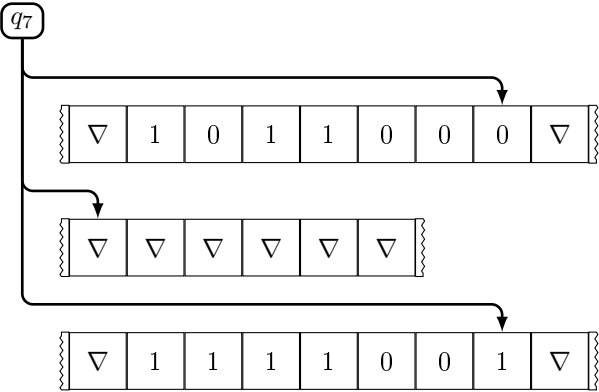
$$K_{52} = (q_1, 1011000\uparrow \nabla, \uparrow \nabla, 1111001\uparrow \nabla)$$

54.



$$K_{53} = (q_2, 101100\uparrow 0, \uparrow \nabla, 111100\uparrow 1)$$

55.

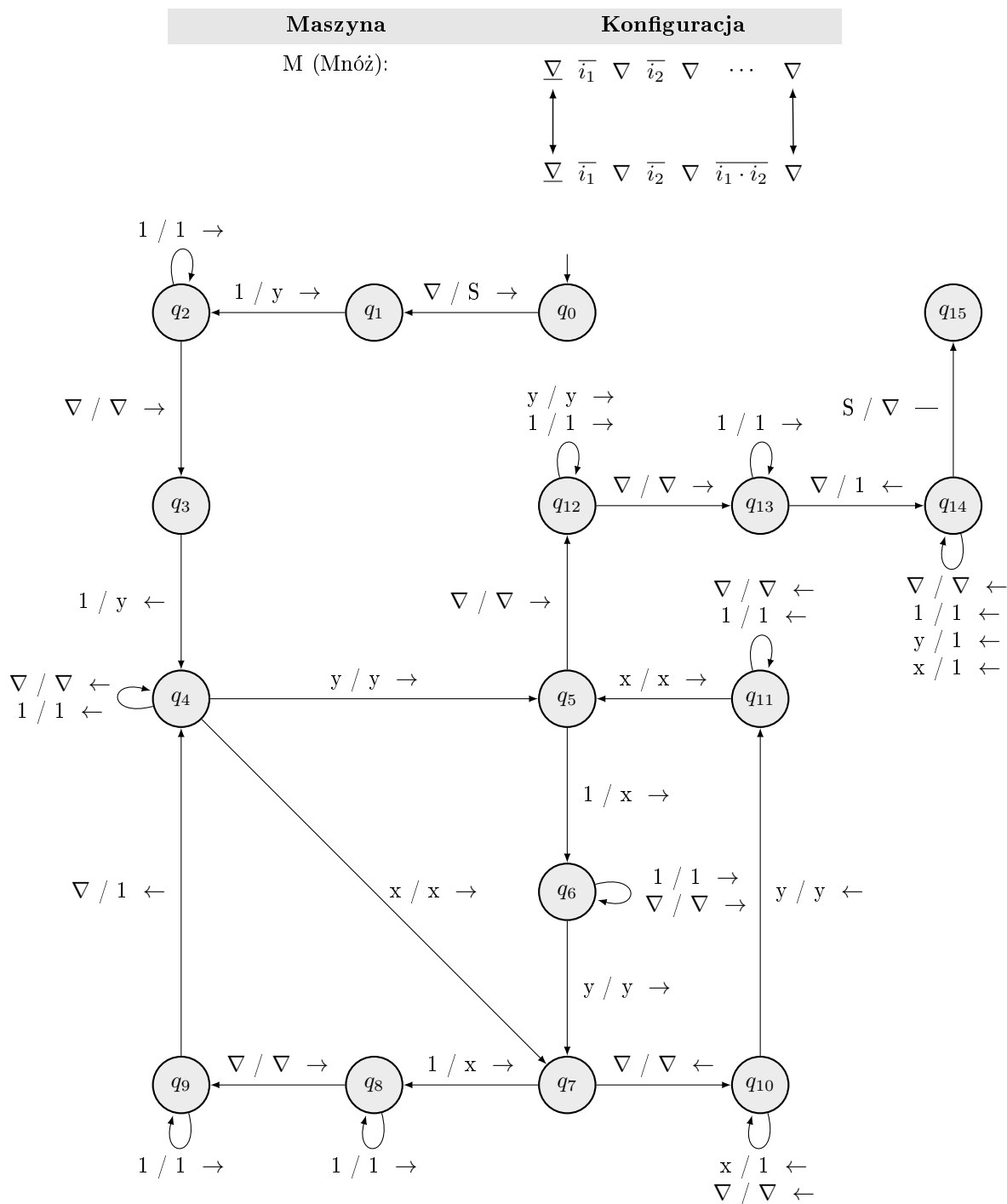


$$K_{54} = (q_7, 101100\uparrow 0, \uparrow \nabla, 111100\uparrow 1)$$

5.5 Zadanie 1.70

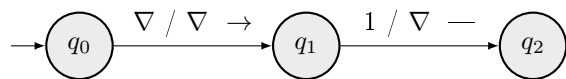
5.5.1 Makra

Makro M (Mnóż)

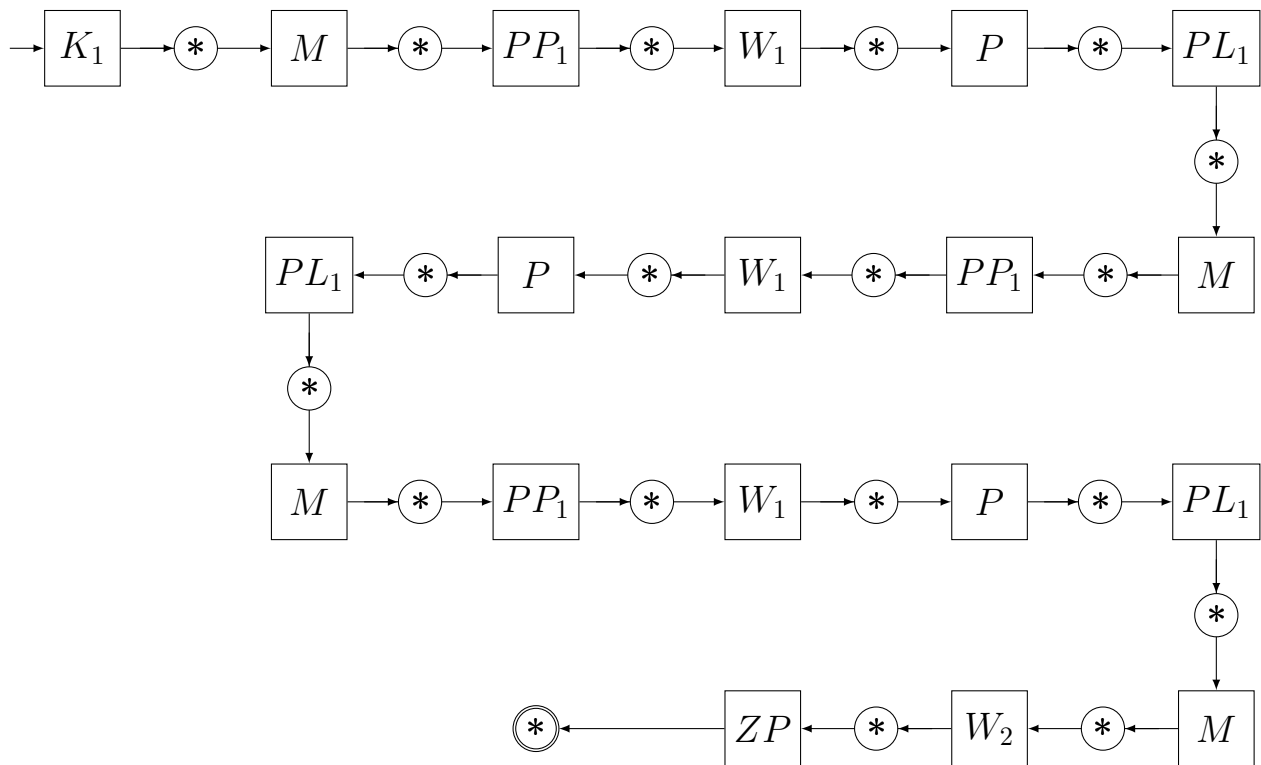


Makro POP (Poprzednik)

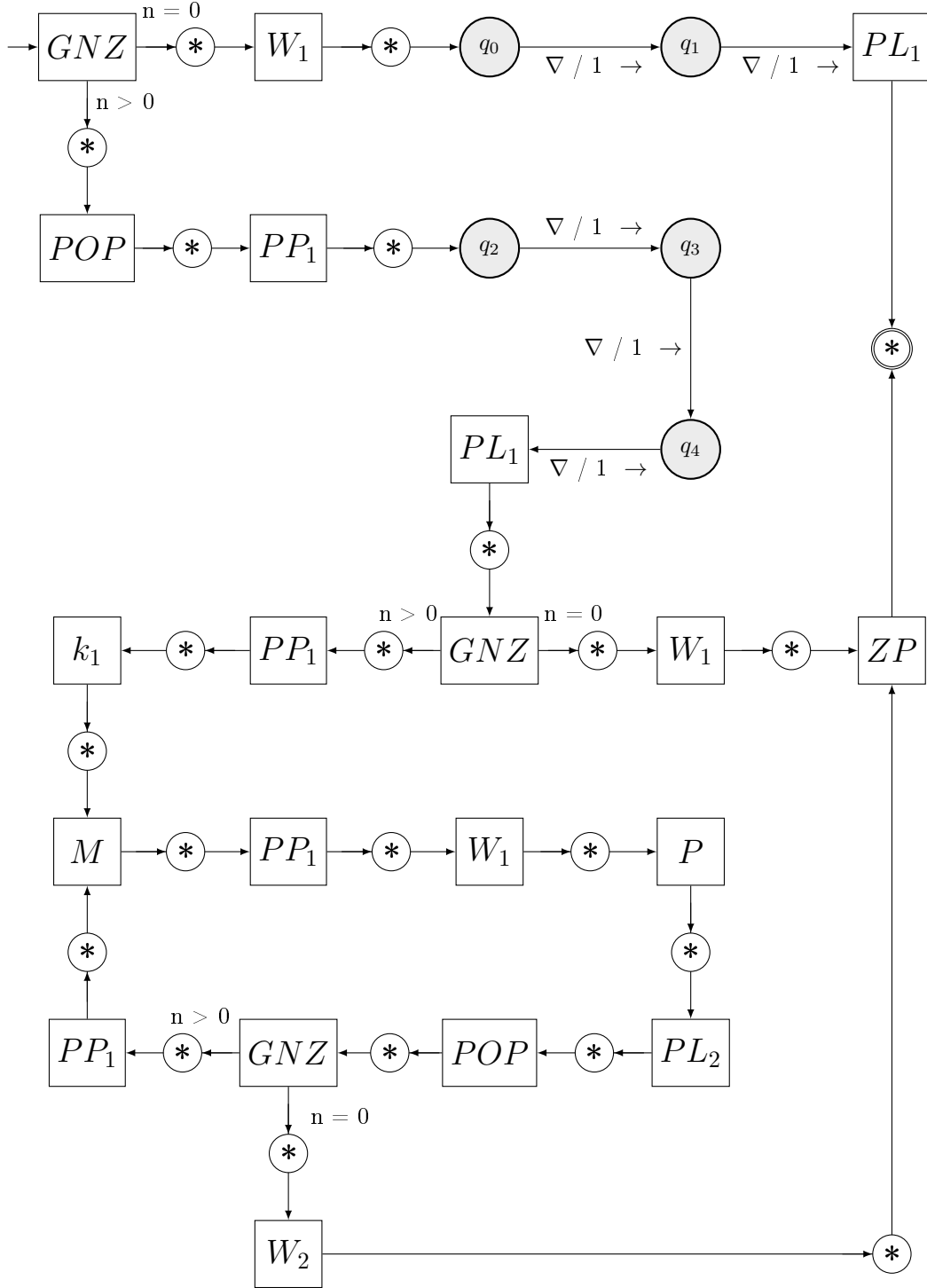
Maszyna	Konfiguracja
POP (Poprzednik):	$ \begin{array}{ccc} \nabla & \overline{i_1} & \nabla \\ \updownarrow & & \updownarrow \\ \nabla & \overline{i_1 - 1} & \nabla \end{array} $



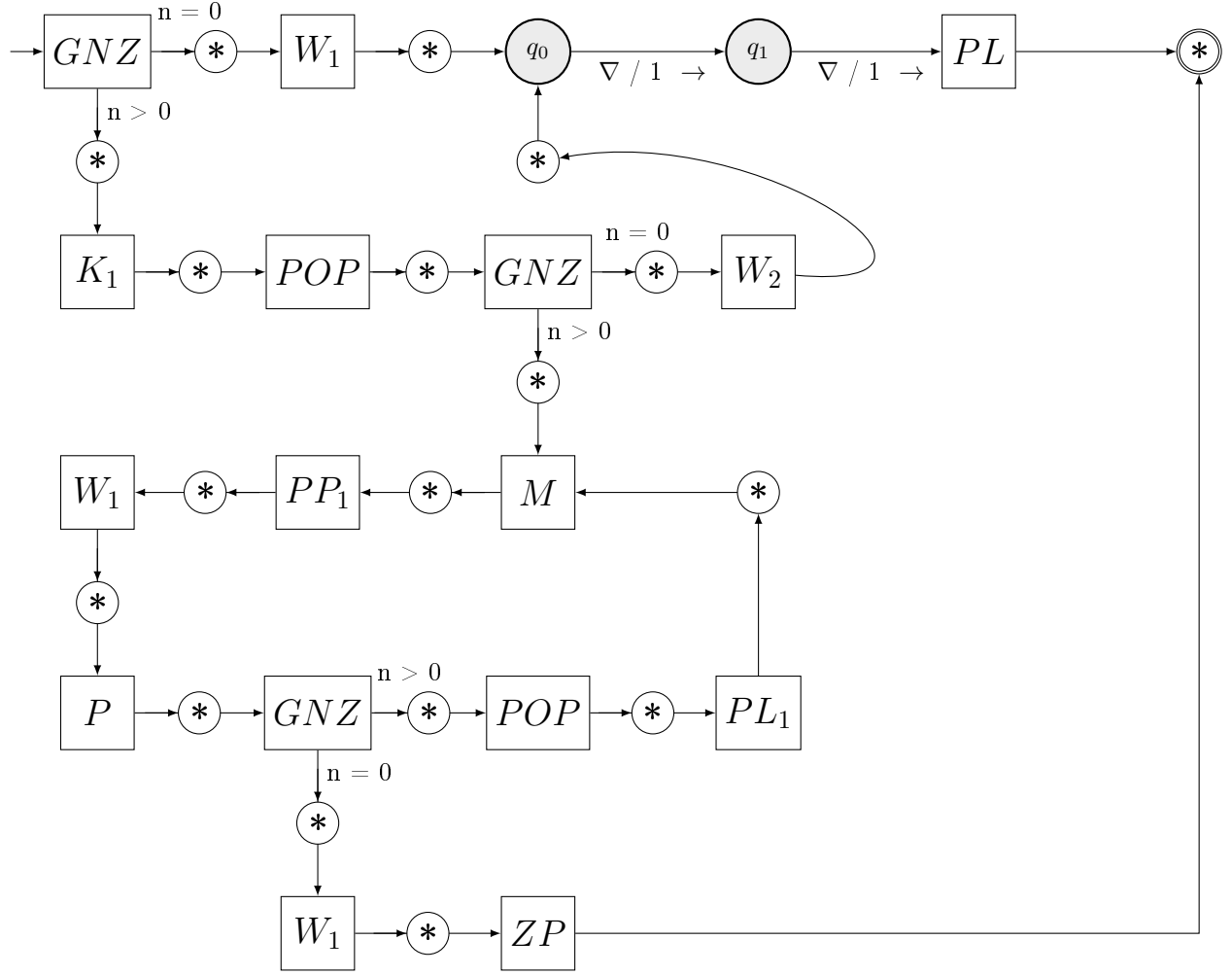
5.5.2 n^5



5.5.3 2^n



5.5.4 $n!$



5.5.5 $n^{n!}$

