THEORETICAL COMPUTER SCIENCE TUTORING (1)

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Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

Let L be the set of strings $s = \langle x_1 x_2 \dots x_n \rangle$ of even length such that: 👌

- $x_i \in \{a, b\}$, for $i = 1, \dots, \frac{n}{2}$ 👌
- $x_i \in \{c, d\}$, for $i = \frac{n}{2} + 1, \dots, n$ 👌
- $x_i = \mathrm{a} \Leftrightarrow x_{n-i+1} = c$, for $i = 1, \dots, \frac{n}{2}$ 👌
- $x_i = b \Leftrightarrow x_{n-i+1} = d$, for $i = 1, \dots, \frac{n}{2}$ 👌

a	b	a	c	d	c

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- $x_i \in \{c, d\}$, for $i = \frac{n}{2} + 1, \dots, n$
- $x_i = \text{a} \Leftrightarrow x_{n-i+1} = c$, for $i = 1, \dots, \frac{n}{2}$
- $x_i = b \Leftrightarrow x_{n-i+1} = d$, for $i = 1, \dots, \frac{n}{2}$

a	**a**	**b**	**b**	**d**	**d**	**c**	**c**

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

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- $x_i \in \{c, d\}$, for $i = \frac{n}{2} + 1, \dots, n$
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- $x_i = b \Leftrightarrow x_{n-i+1} = d$, for $i = 1, \dots, \frac{n}{2}$

a	**b**	**a**	**d**	**c**

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

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- $x_i = \mathrm{a} \Leftrightarrow x_{n-i+1} = c$, for $i = 1, \dots, \frac{n}{2}$ 👎
- $x_i = b \Leftrightarrow x_{n-i+1} = d$, for $i = 1, \dots, \frac{n}{2}$ 👎

a	a	b	b	a	d	d	d	c	c

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

Let L be the set of strings $s = \langle x_1 x_2 \dots x_n \rangle$ of even length such that:

- $x_i \in \{a, b\}$, for $i = 1, \dots, \frac{n}{2}$
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- $x_i = b \Leftrightarrow x_{n-i+1} = d$, for $i = 1, \dots, \frac{n}{2}$

Define a deterministic Turing Machine that accepts all and only the words contained in $\boldsymbol{L}$

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it) 🤔

Let $s = \langle x_1 x_2 \dots x_n \rangle \in \{a, b, c, d\}^n$ e $\sigma = \langle y_1 y_2 \dots y_n \rangle \in \{0,1\}^n$ the binary string associated with s according to the following rules:

- $y_i = 0 \Leftrightarrow x_i = a \vee x_i = c$, per $1 \leq i \leq n$
- $y_i = 1 \Leftrightarrow x_i = b \vee x_i = d$, per $1 \leq i \leq n$

a	b	a	c	d	c

1	0	1	1	0	1

b	b	a	d	d	d

0	0	1	0	0	0

💡 I just have to check if the string is palindrome

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

Let $s = \langle x_1 x_2 \ldots x_n \rangle \in \{a, b, c, d\}^n$ e $\sigma = \langle y_1 y_2 \ldots y_n \rangle \in \{0,1\}^n$ the binary string associated with s according to the following rules:

- $y_i = 0 \Leftrightarrow x_i = a \lor x_i = c$, for $1 \le i \le n$
- $y_i = 1 \Leftrightarrow x_i = b \lor x_i = d$, for $1 \le i \le n$

is σ palindrome?

2 possible ways:

- Transform the string and check if it is a palindrome using the appropriate Turing machine
- Modify the Turing machine that checks if a string is palindrome

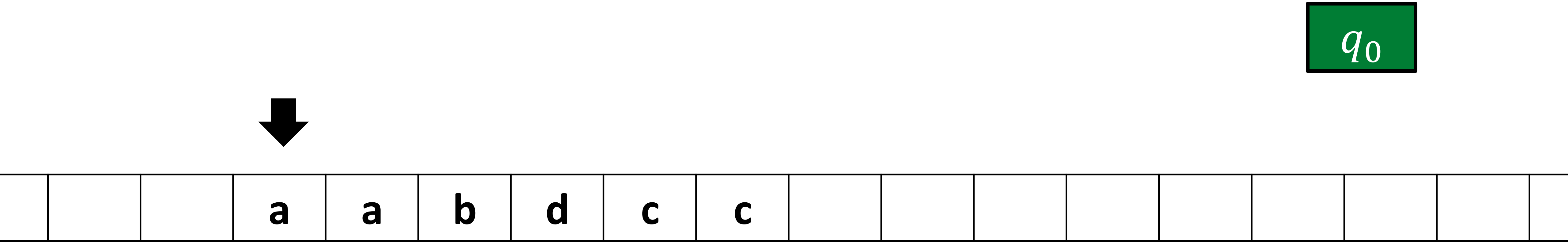
control & transform s → is σ palindrome?

Modified TM

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{a, b, c, d, \square\}$

$Q \;=\; \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$



$\langle \mathrm{q}_0, a, \square, q_a, right \rangle$

similar if I find b

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{a, b, c, d, \square\}$

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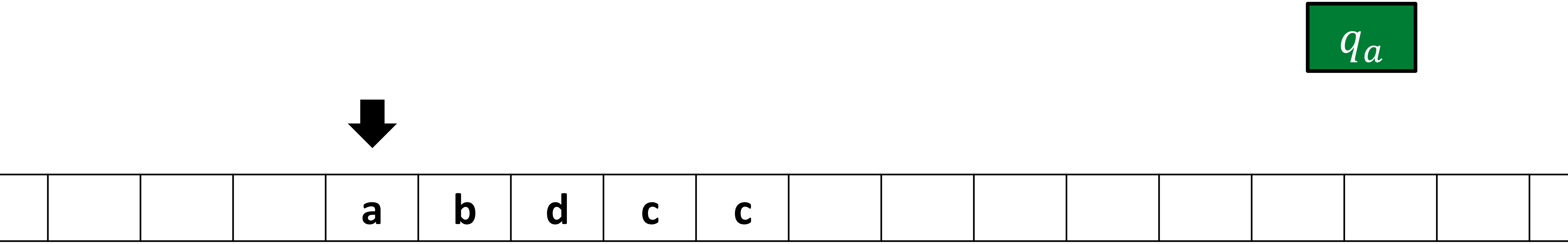
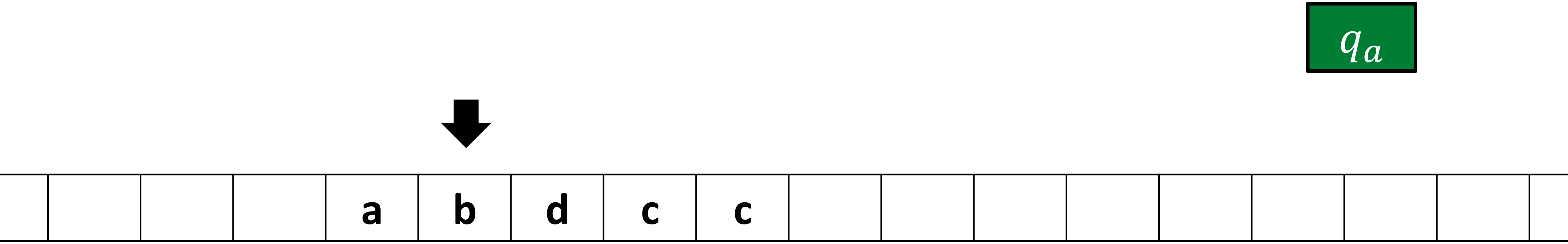


$$\langle \mathrm{q}_a, a, a, q_a, right \rangle$$

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

$$\Sigma = \{a, b, c, d, \square\}$$
$$Q \;=\; \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$$

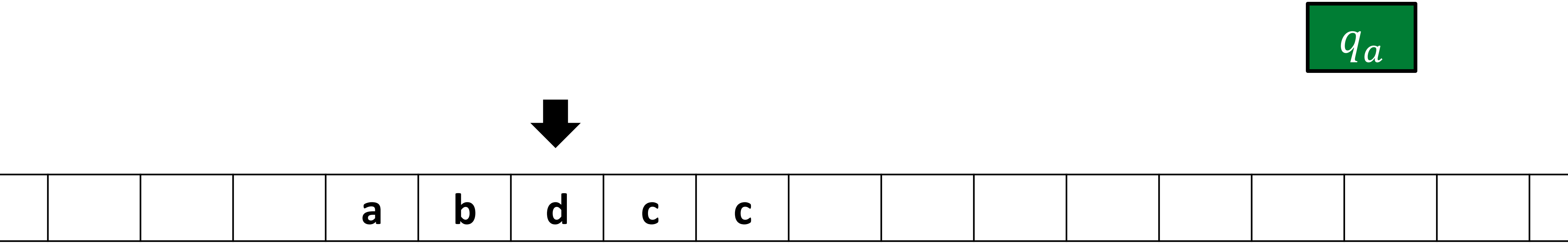


$$\langle q_a, b, b, q_a, right\rangle$$

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{a, b, c, d, \square\}$

$Q = \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

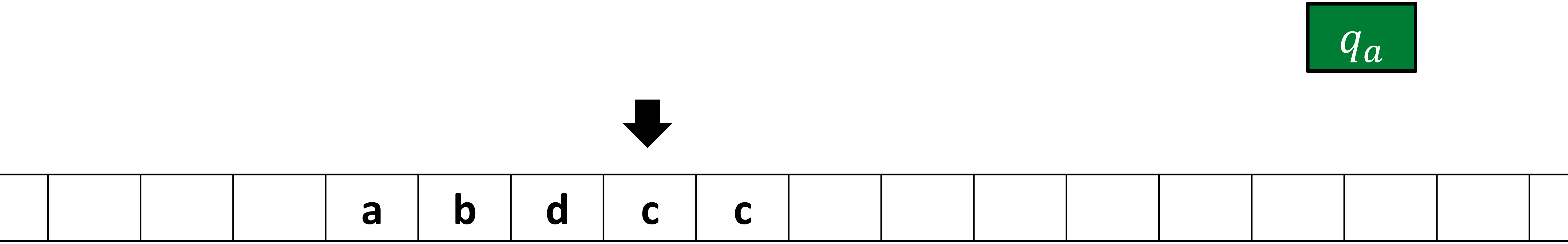


$\langle \mathrm{q}_a, d, d, q_a, right \rangle$

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{a, b, c, d, \square\}$

$Q = \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

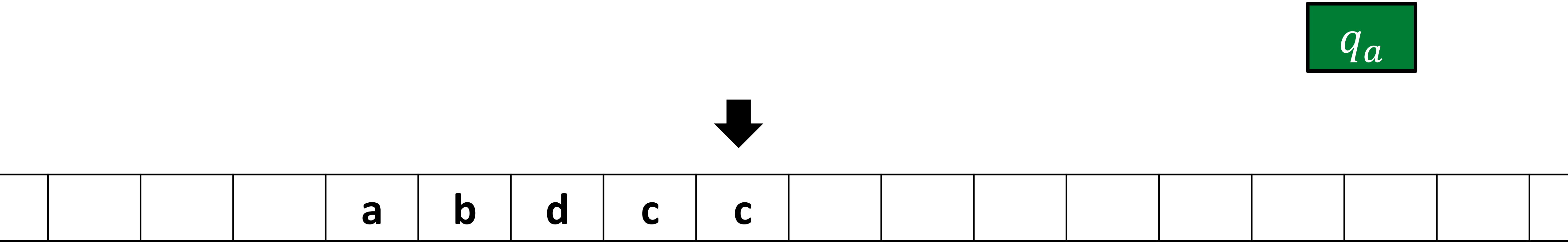


$$\langle q_a, c, c, q_a, right\rangle$$

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{a, b, c, d, \square\}$

$Q \;=\; \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

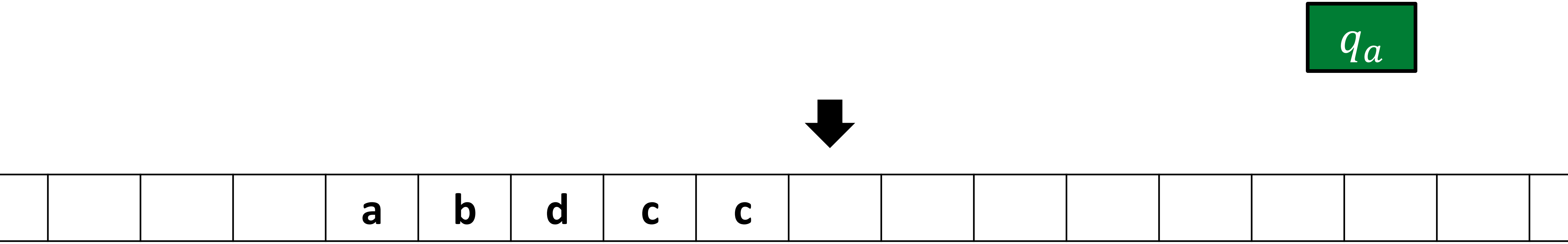


$\langle q_a, c, c, q_a, right \rangle$

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{a, b, c, d, \square\}$

$Q = \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

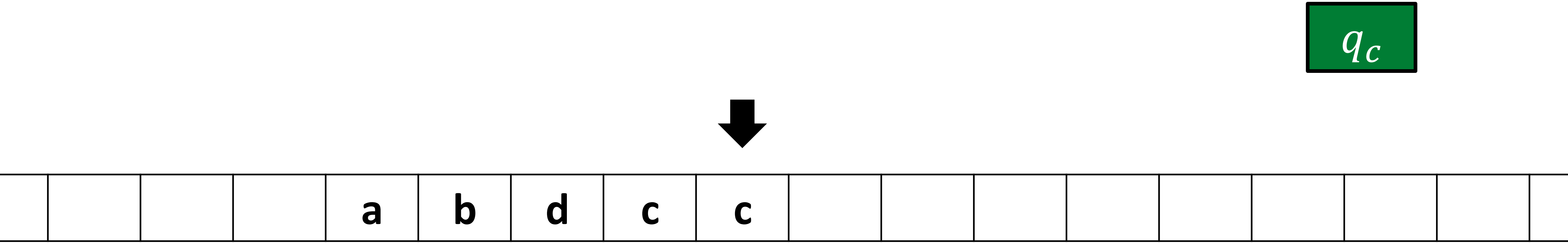


$\langle q_a, \square, \square, q_c, left \rangle$

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{a, b, c, d, \square\}$

$Q \;=\; \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

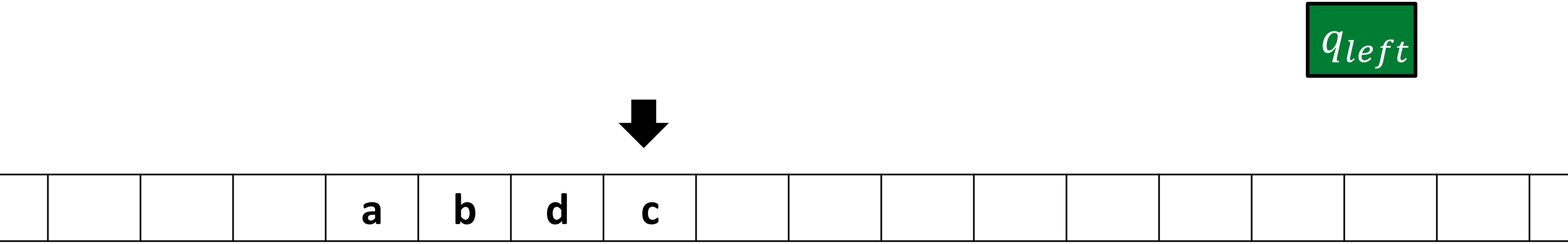


$\langle \mathrm{q}_c, \mathrm{c}, \square, q_{left}, left \rangle$

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{a, b, c, d, \square\}$

$Q \ = \ \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

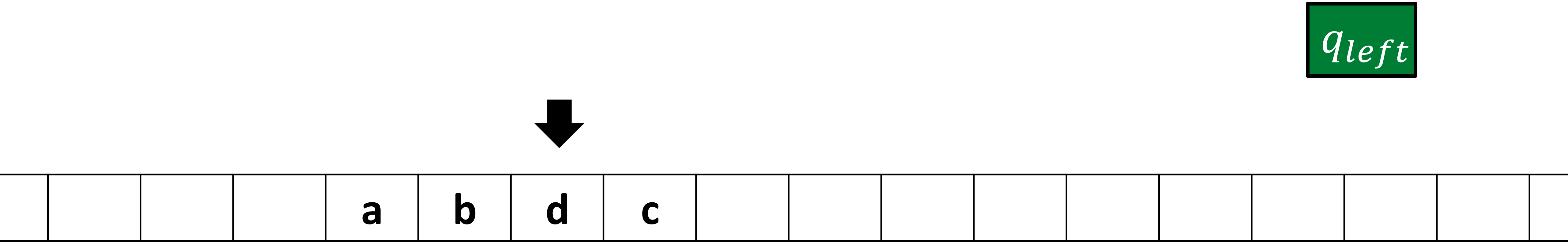


$$\langle q_{left}, c, c, q_{left}, left \rangle$$

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]()

$\Sigma = \{a, b, c, d, \square\}$

$Q \ = \ \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

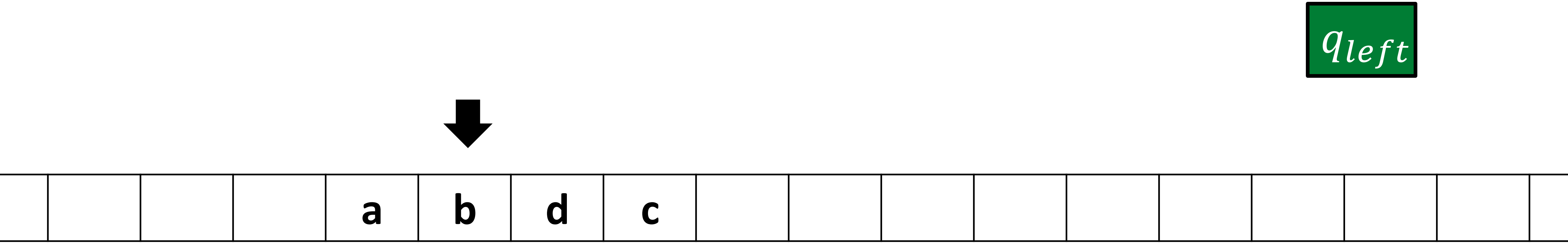


$\langle \mathrm{q}_{left}, d, d, q_{left}, left \rangle$

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{a, b, c, d, \square\}$

$Q \;=\; \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

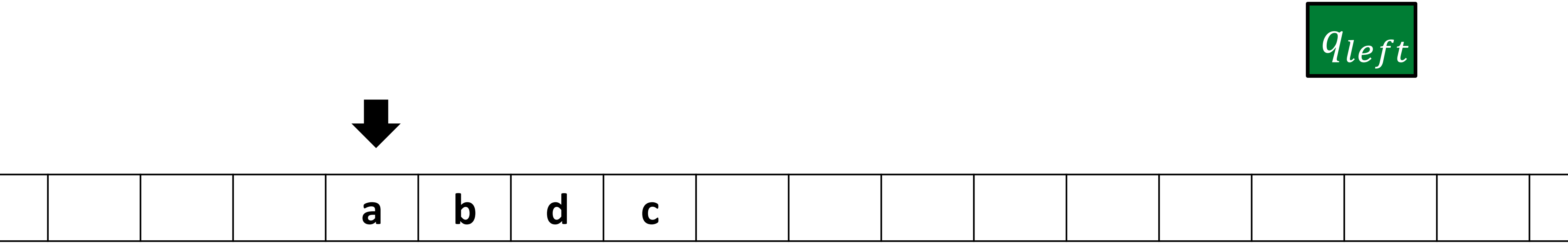


$$\langle \mathrm{q}_{left}, b, b, q_{left}, left \rangle$$

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{a, b, c, d, \square\}$

$Q \ = \ \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$



$$\langle \mathrm{q}_{left}, a, a, q_{left}, left \rangle$$

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{a, b, c, d, \square\}$

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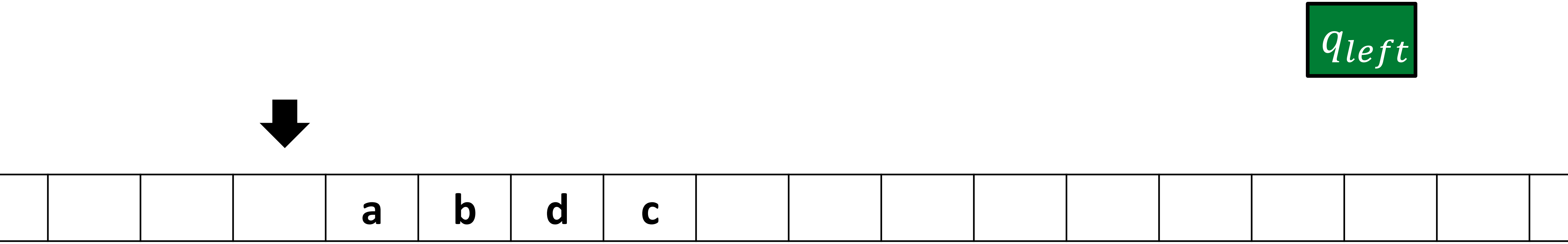
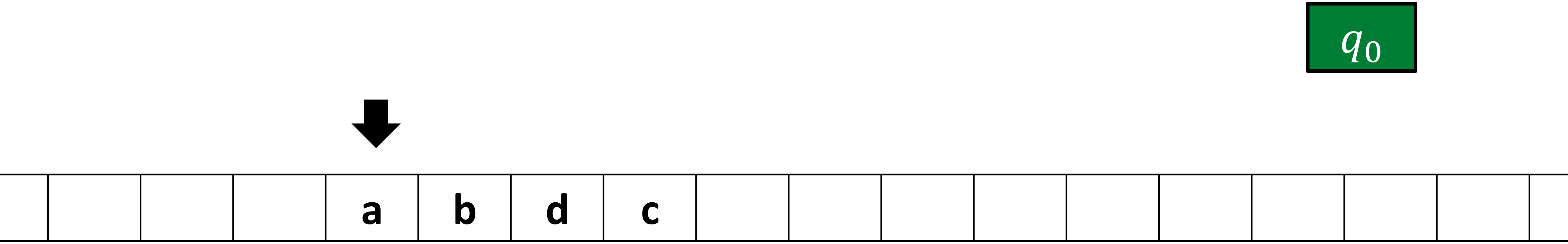


$$\langle q_{left}, \square, \square, q_0, right \rangle$$

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{a, b, c, d, \square\}$
$Q = \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

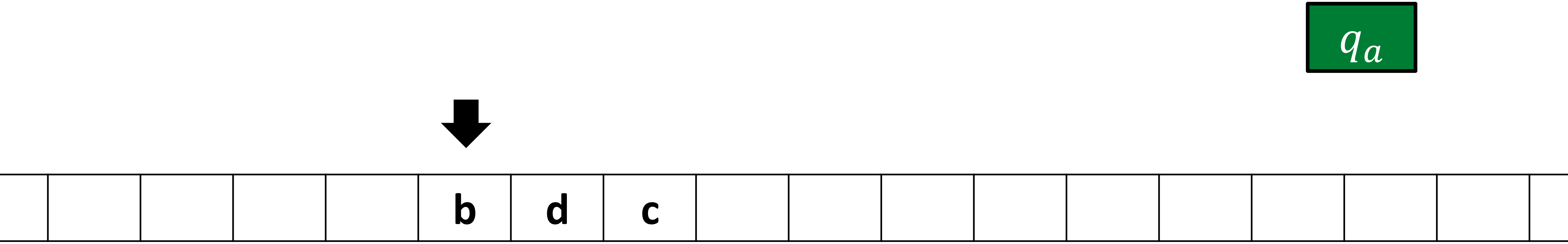


$\langle q_0, a, \square, q_a, right \rangle$

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{a, b, c, d, \square\}$

$Q = \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$



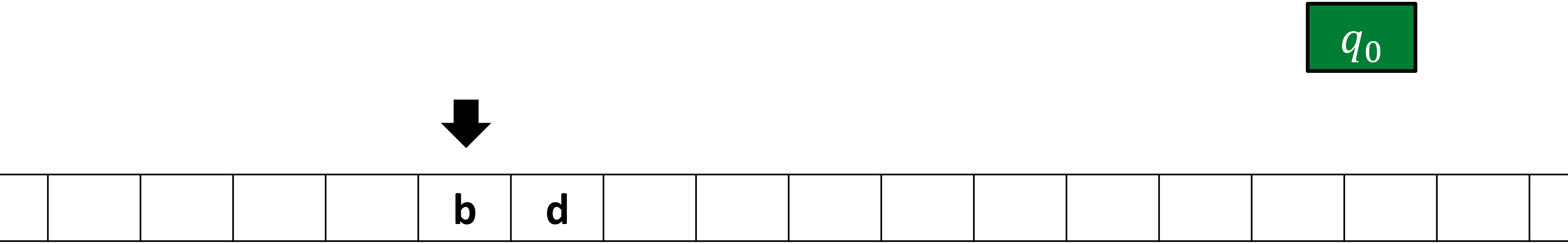
$$\langle q_a, b, b, q_a, right \rangle$$

...

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{a, b, c, d, \square\}$

$Q = \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

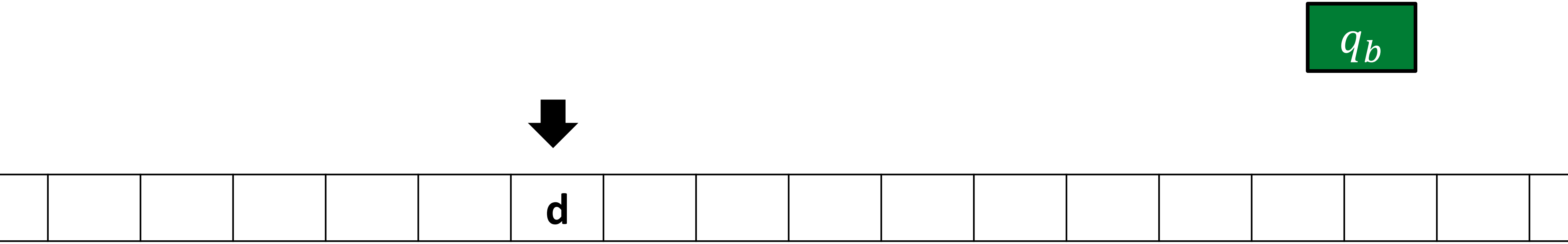


$\langle q_0, b, \square, q_b, right\rangle$

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{a, b, c, d, \square\}$

$Q = \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$



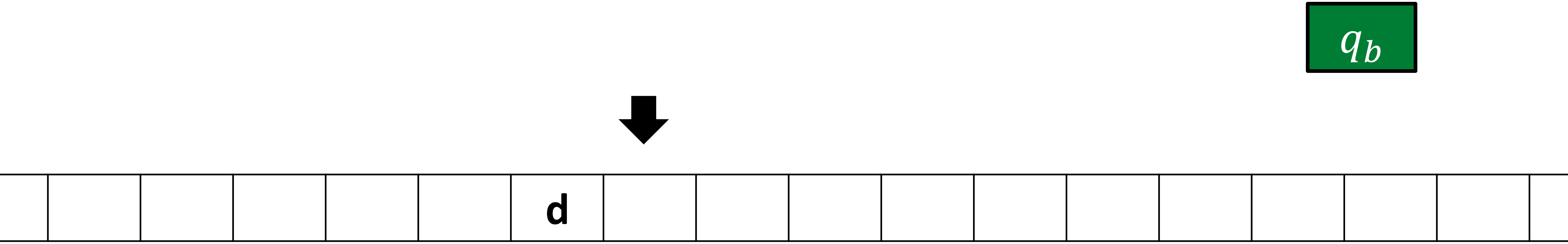
$$\langle q_b, d, d, q_b, right\rangle$$

similar if I find a, b or c

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{a, b, c, d, \square\}$

$Q \;=\; \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

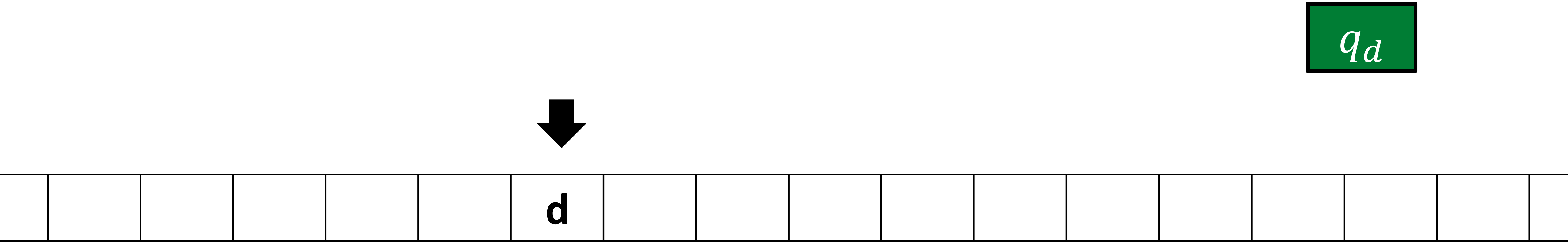


$\langle q_b, \square, \square, q_d, left \rangle$

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{a, b, c, d, \square\}$

$Q = \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

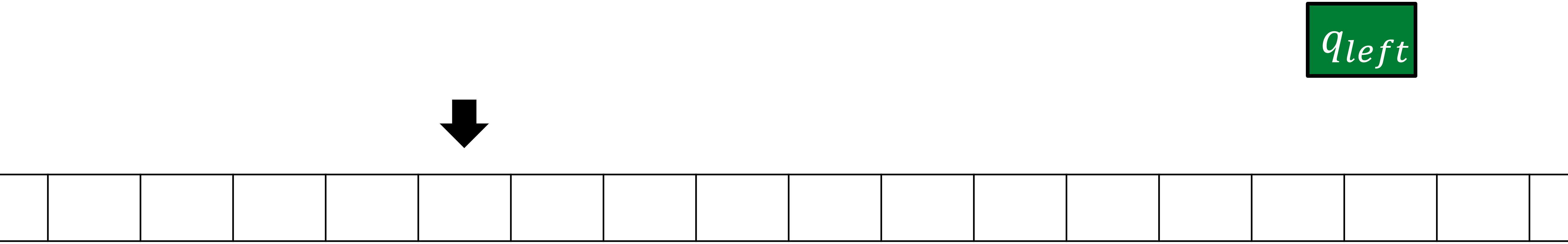


$$\langle \mathrm{q}_d, d, \square, q_{left}, left \rangle$$

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{a, b, c, d, \square\}$

$Q = \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

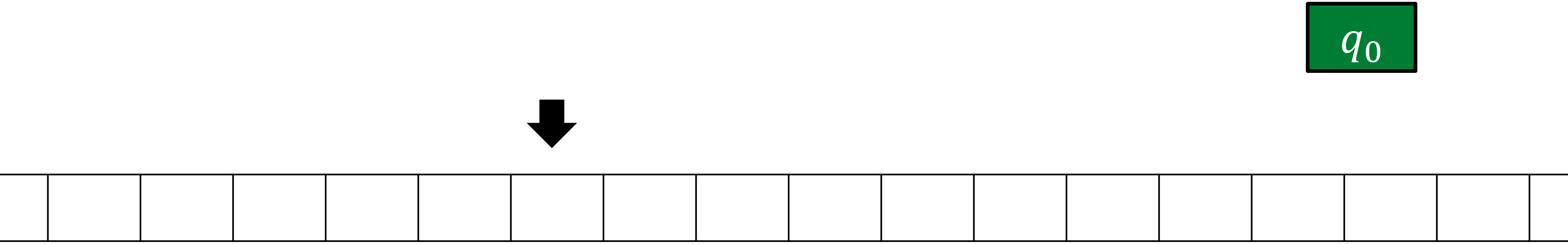


$\langle q_{ind}, \square, \square, q_0, right \rangle$

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{a, b, c, d, \square\}$

$Q \; = \; \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

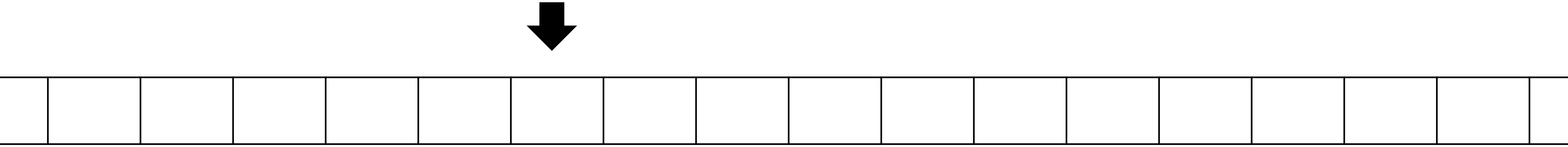


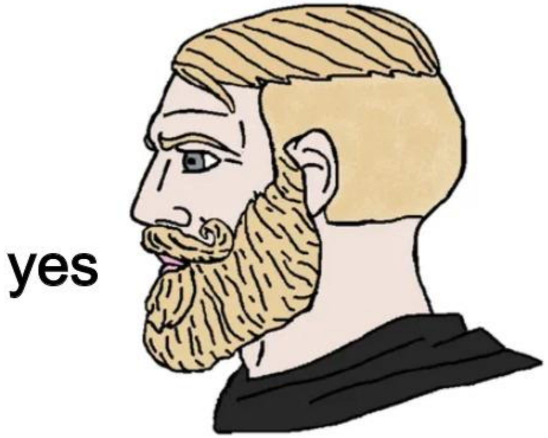
$$\langle q_0, \square, \square, q_{acc}, stop\rangle$$

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

$$\Sigma = \{a, b, c, d, \square\}$$
$$Q = \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$$

q_{acc}

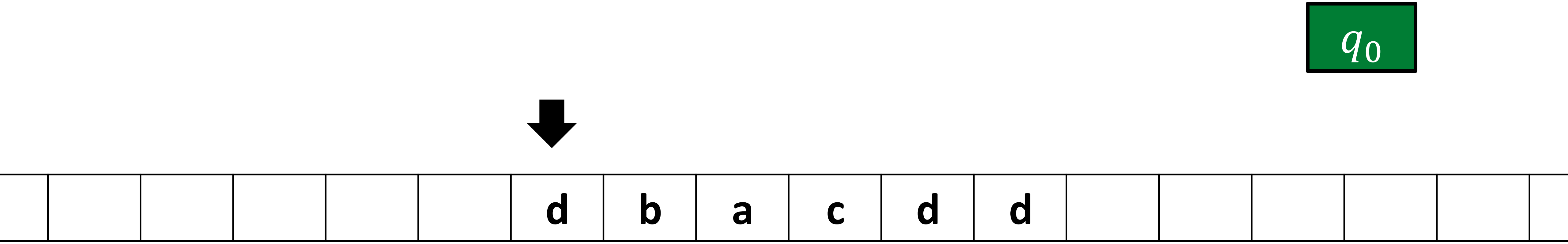




Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{a, b, c, d, \square\}$

$Q = \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$



$\langle q_0, d, d, q_{rej}, stop \rangle$

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{a, b, c, d, \square\}$

$Q = \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

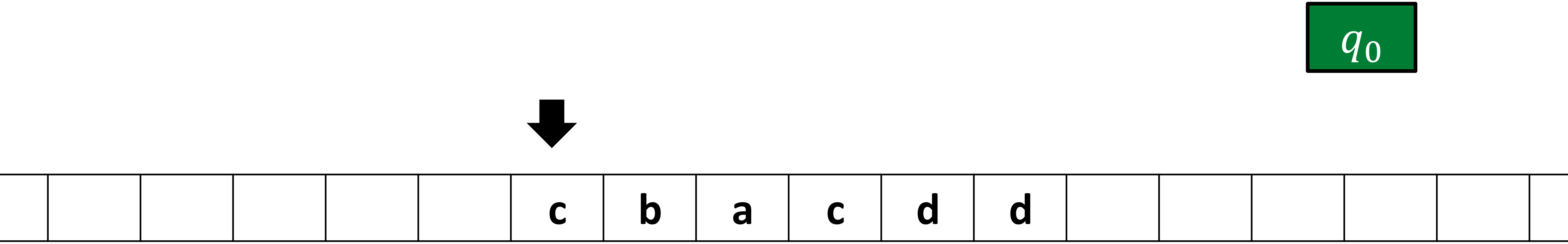
q_{rej}

						d	**b**	**a**	**c**	**d**	**d**					

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{a, b, c, d, \square\}$

$Q \;=\; \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$



$\langle \mathrm{q}_0, c, c, q_{rej}, stop \rangle$

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{a, b, c, d, \square\}$

$Q \;=\; \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

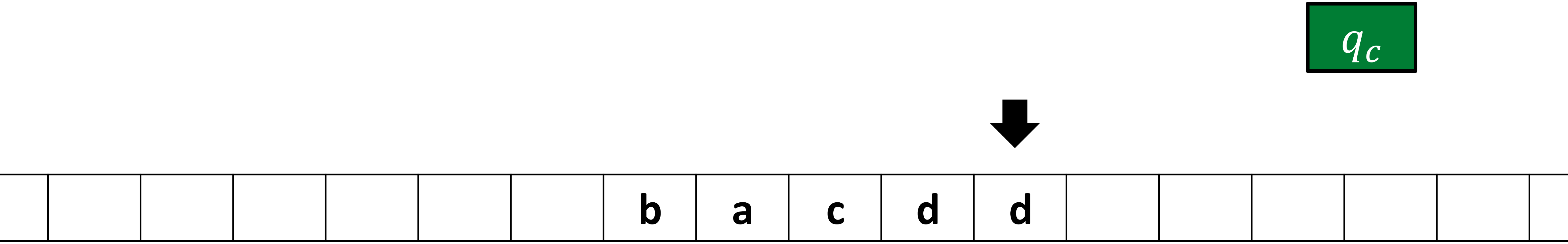
q_{rej}

						c	b	a	c	d	d						

Problem 2.1 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{a, b, c, d, \square\}$

$Q \; = \; \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$



$$\langle \mathrm{q}_c, d, d, q_{rej}, stop \rangle$$

similar if I find a, b or $\square$

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

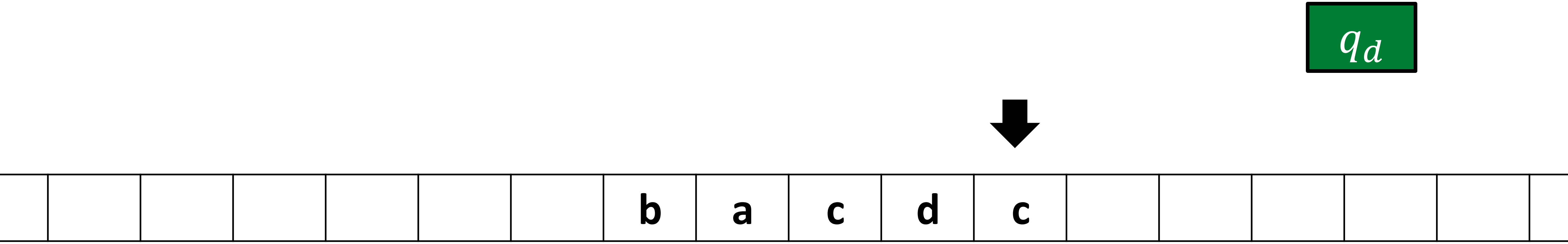
$\Sigma = \{a, b, c, d, \square\}$
$Q \ = \ \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

q_{rej}

							b	a	c	d	d						

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]()

$\Sigma = \{a, b, c, d, \square\}$
$Q = \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$



$$\langle q_c, c, c, q_{rej}, stop \rangle$$

similar if I find a, b or $\square$

Problem 2.1 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{a, b, c, d, \square\}$
$Q \;=\; \{q_0, q_a, q_b, q_c, q_d, q_{left}, q_{acc}, q_{rej}\}$

q_{rej}

							b	a	c	d	c					

Problem 2.3 from EsMacchineTuring.pdf (uniroma2.it)

Design a Turing machine that computes the two functions described below:

- $f(n,k) = \left\lceil \frac{n}{k} \right\rceil$
- $g(n,k) = \left\lfloor \frac{n}{k} \right\rfloor$

n
k
$f(n,k)$
$g(n,k)$

Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

Es.

$n = 15, k = 6$

$f(15,6) = 3$

$g(15,6) = 2$

$$\overbrace{1\;1\;1\;1\;1\;1\;1\;1\;1\;1\;1\;1\;1\;1\;1}^{\#1 \;=\; 15}$$

$$\underbrace{1\;1\;1\;1\;1\;1}_{\#1 \;=\; 6}\;\underbrace{1\;1\;1\;1\;1\;1}_{\#1 \;=\; 6}\;1\;1\;1$$

Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

Es.

$n = 1111111, k = 111$

$f(1111111{,}111) = 111, g(1111111{,}111) = 11$

q_f

				1	1	1	1	1	1	1							

				1	1	1											

				1	1	1											

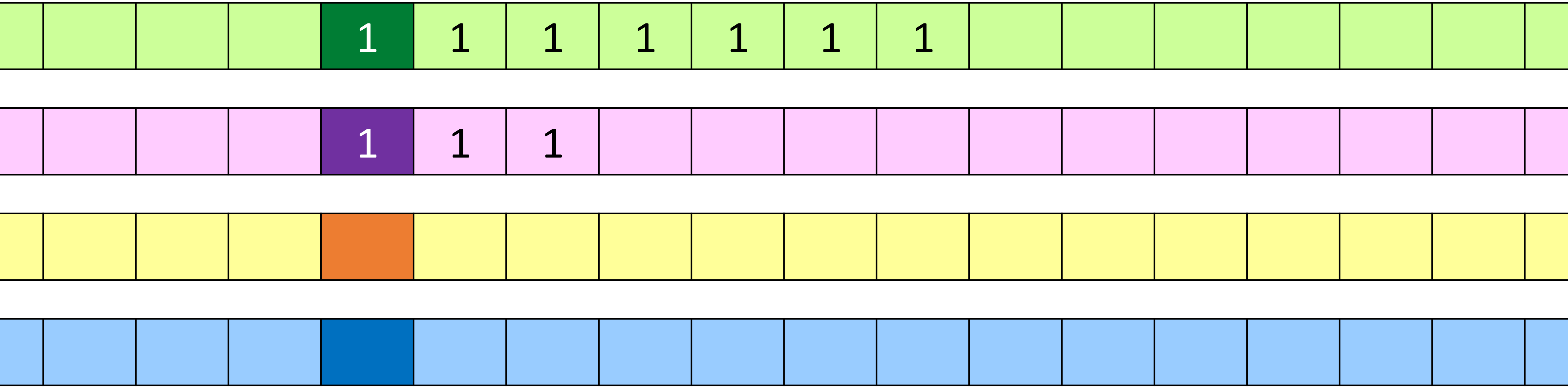
				1	1												

Problem 2.3 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle q_0, (1,1,\square,\square), (1,1,1,\square), q_1, (r,r,r,s) \rangle$

q_0

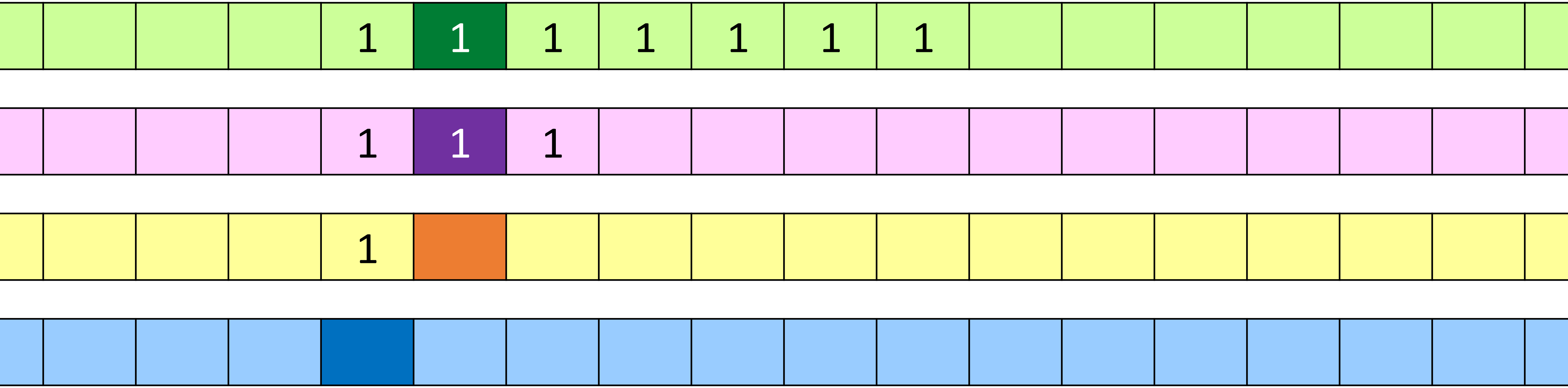


Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle q_1, (1,1,\square,\square), (1,1,\square,\square), q_1, (r,r,s,s) \rangle$

q_1

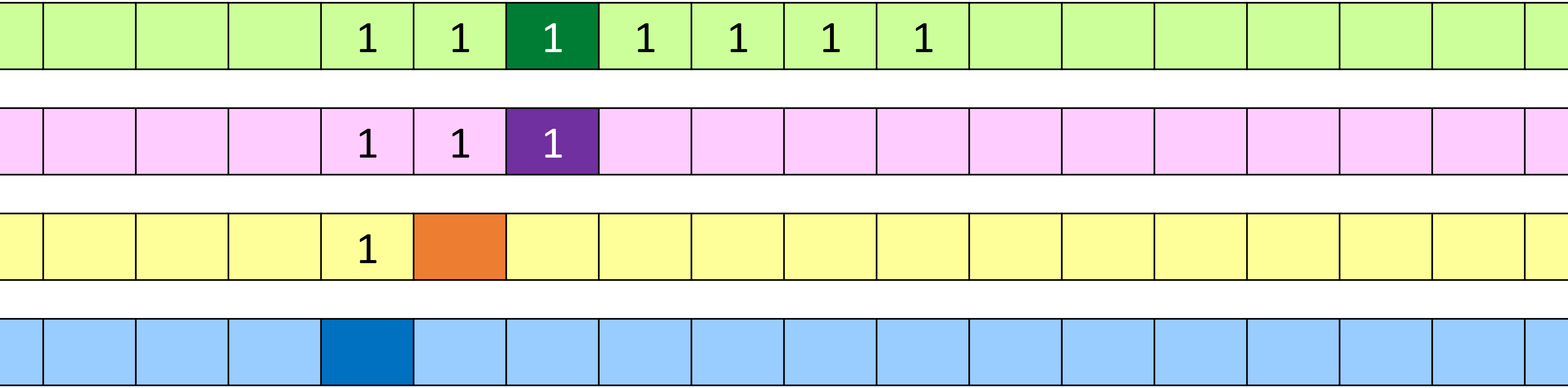


Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]()

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle q_1, (1,1,\square,\square), (1,1,\square,\square), q_1, (r, r, s, s) \rangle$

q_1

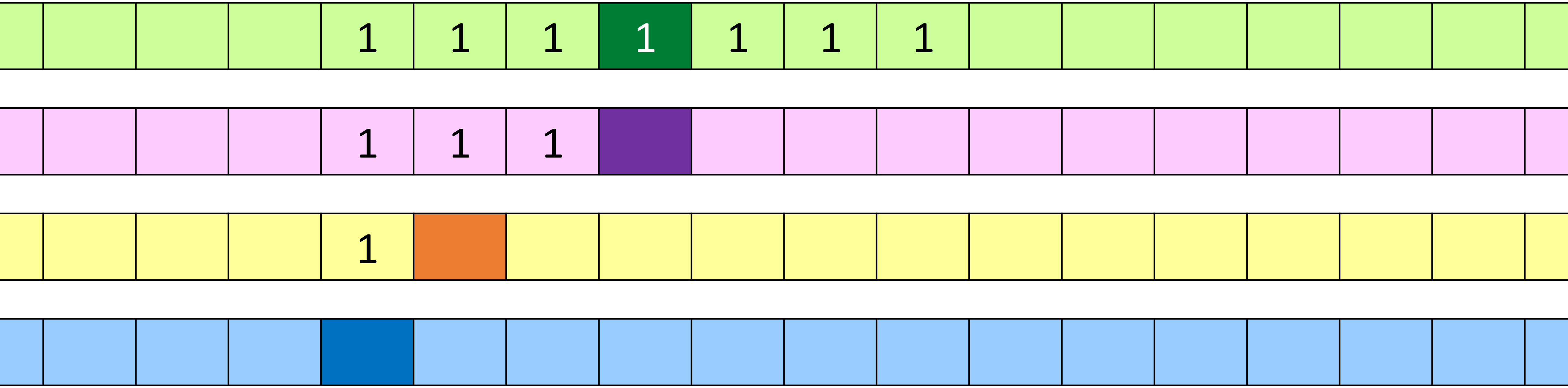


Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{1,\square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle q_1, (1,\square,\square,\square), (1,\square,\square,1), q_2, (s,l,s,r) \rangle$

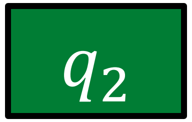
q_1

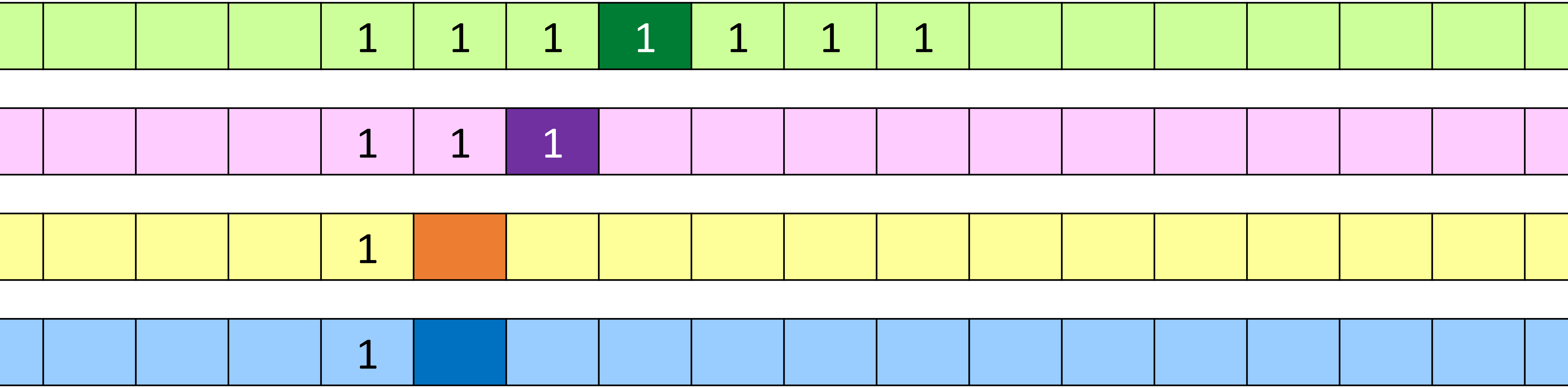


Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle q_2, (1,1,\square,\square), (1,1,\square,\square), q_2, (s, l, s, s) \rangle$



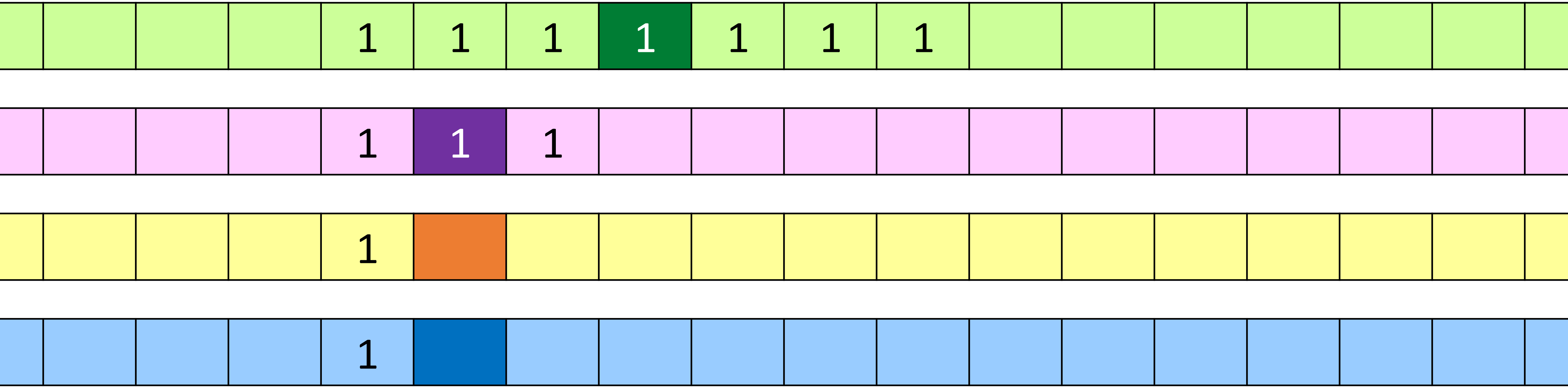


Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle q_2, (1,1,\square,\square), (1,1,\square,\square), q_2, (s, l, s, s) \rangle$

q_2

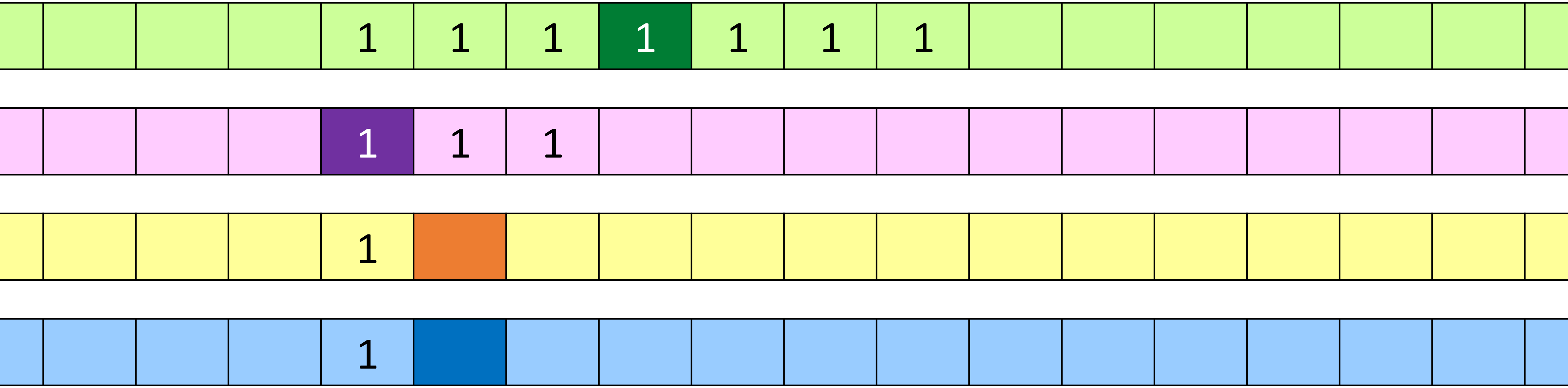


Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle q_2, (1,1,\square,\square), (1,1,\square,\square), q_2, (s, l, s, s) \rangle$

q_2

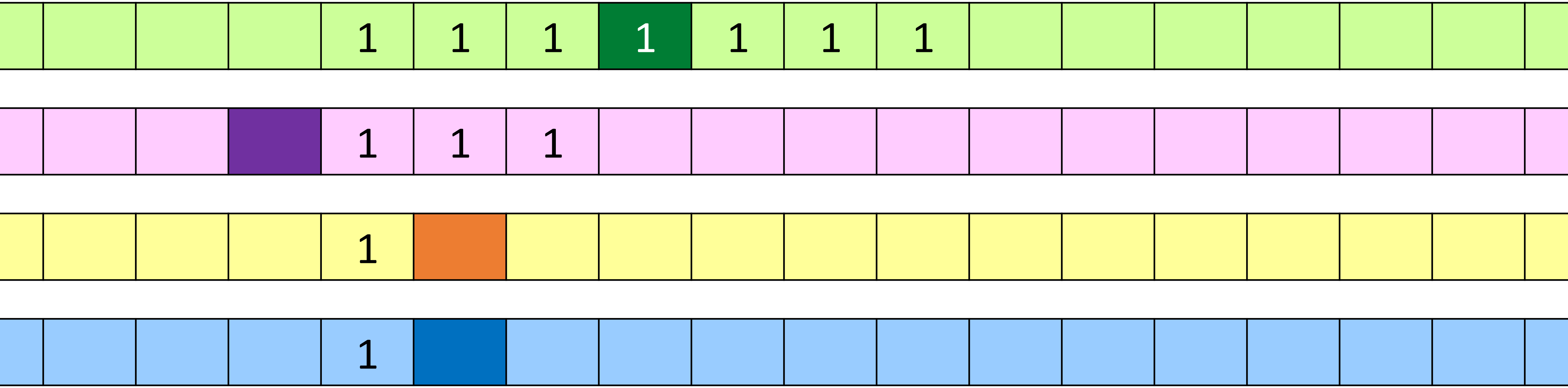


Problem 2.3 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{1,\square\}, Q = \{q_0, q_1, q_2, q_f\}$

$$\langle q_2, (1,\square,\square,\square), (1,\square,\square,\square), q_0, (s, r, s, s)\rangle$$

q_2

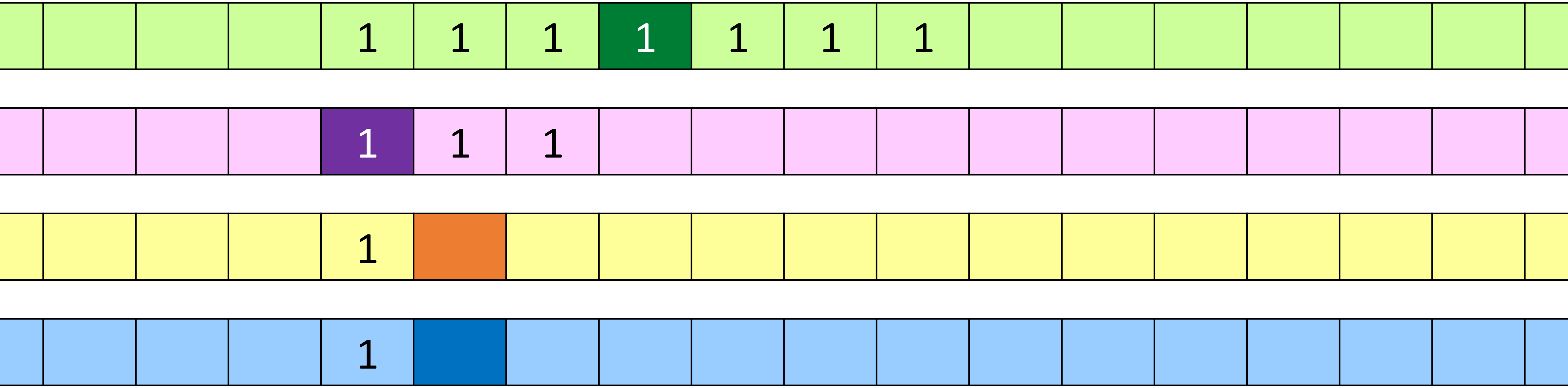


Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle q_0, (1,1,\square,\square), (1,1,1,\square), q_1, (r,r,r,s) \rangle$

q_0

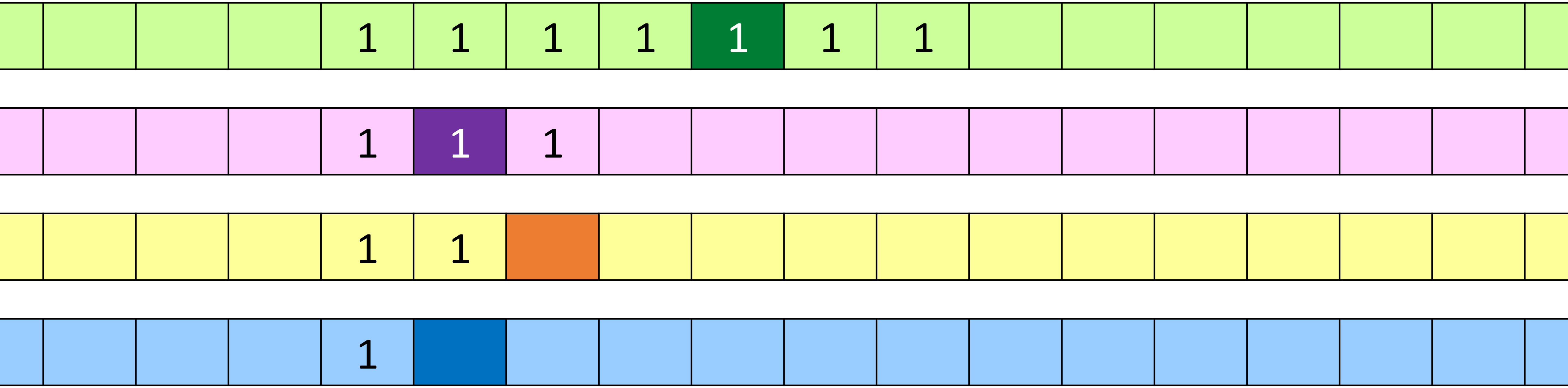


Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle \mathrm{q}_1, (1,1,\square,\square), (1,1,\square,\square), q_1, (r, r, s, s) \rangle$

q_1

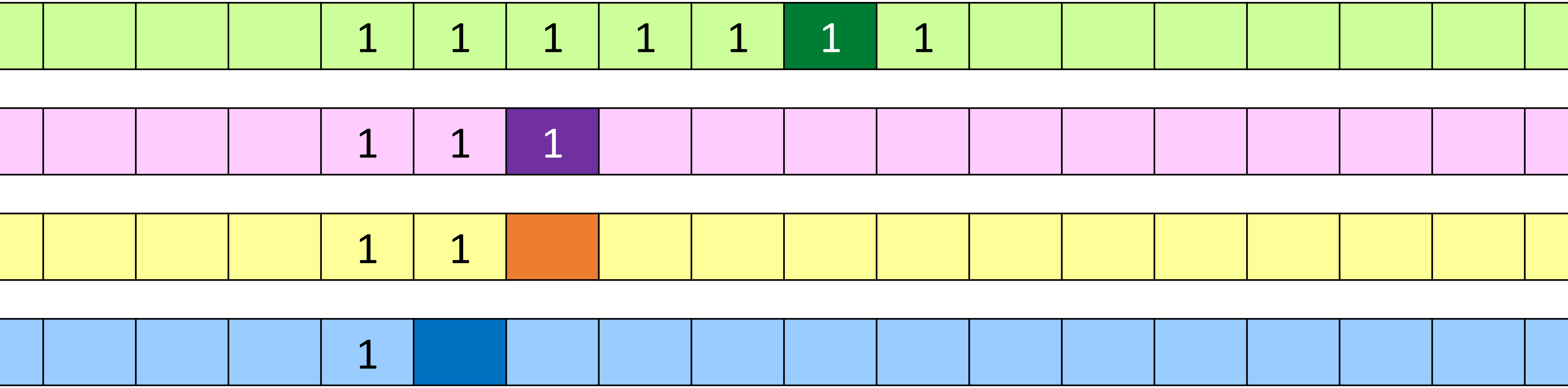


Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle q_1, (1,1,\square,\square), (1,1,\square,\square), q_1, (r,r,s,s) \rangle$

q_1

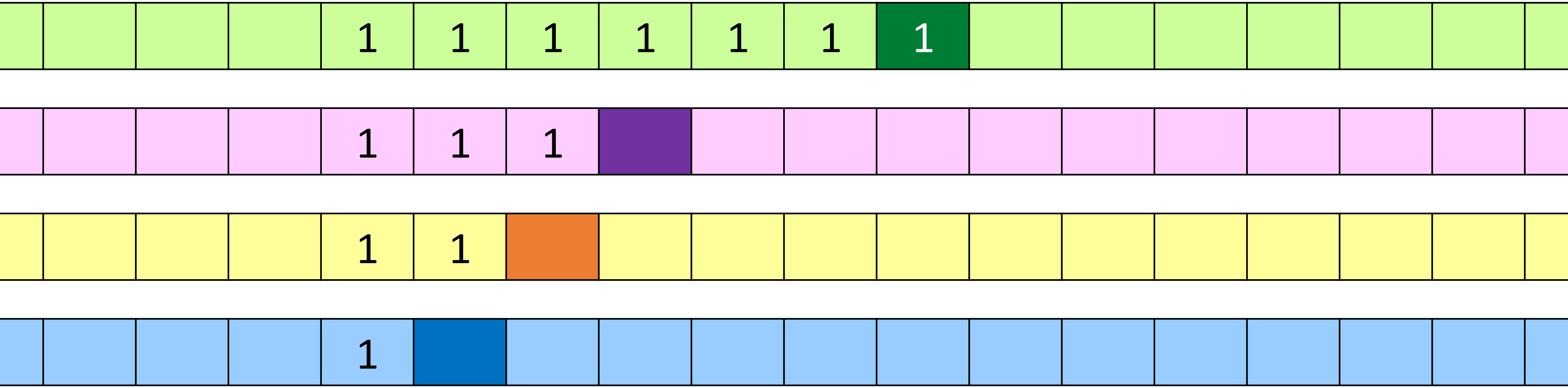


Problem 2.3 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle \mathrm{q}_1, (1, \square, \square, \square), (1, \square, \square, 1), q_2, (s, l, s, r) \rangle$

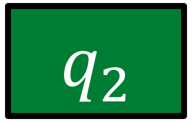
q_1

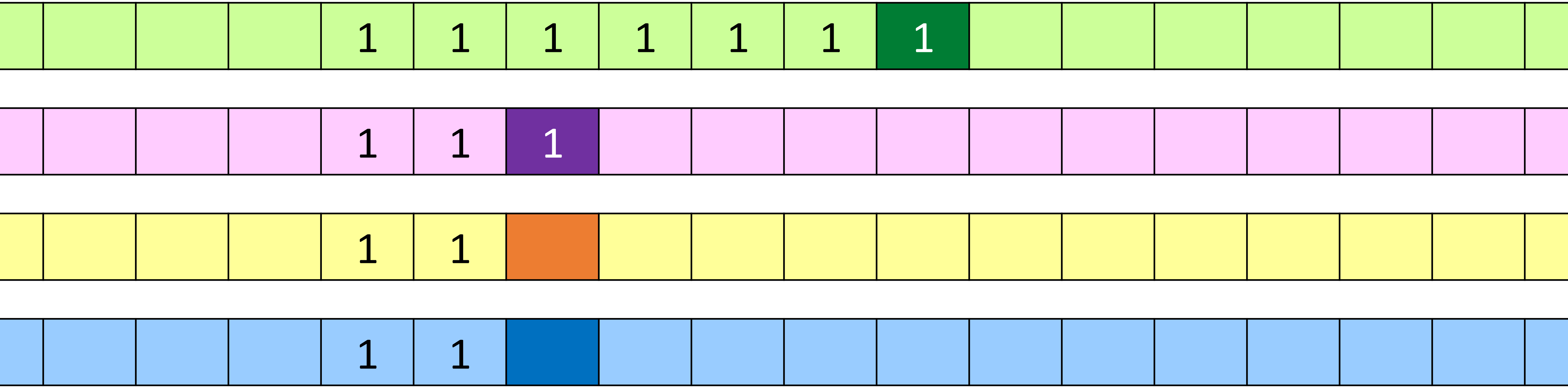


Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle \mathrm{q}_2, (1,1,\square,\square), (1,1,\square,\square), q_2, (s, l, s, s) \rangle$



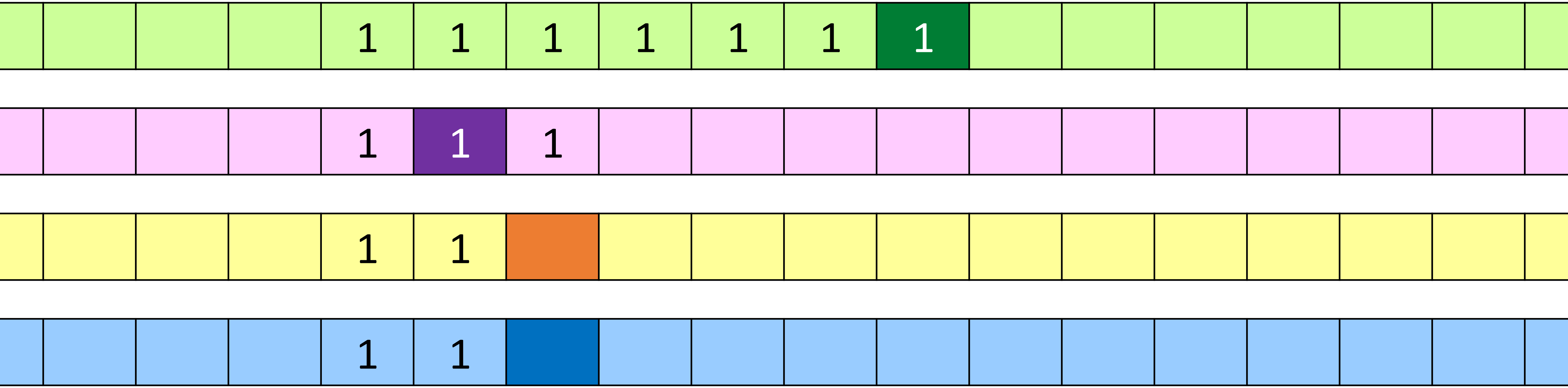


Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle \mathrm{q}_2, (1,1,\square,\square), (1,1,\square,\square), q_2, (s, l, s, s) \rangle$

q_2

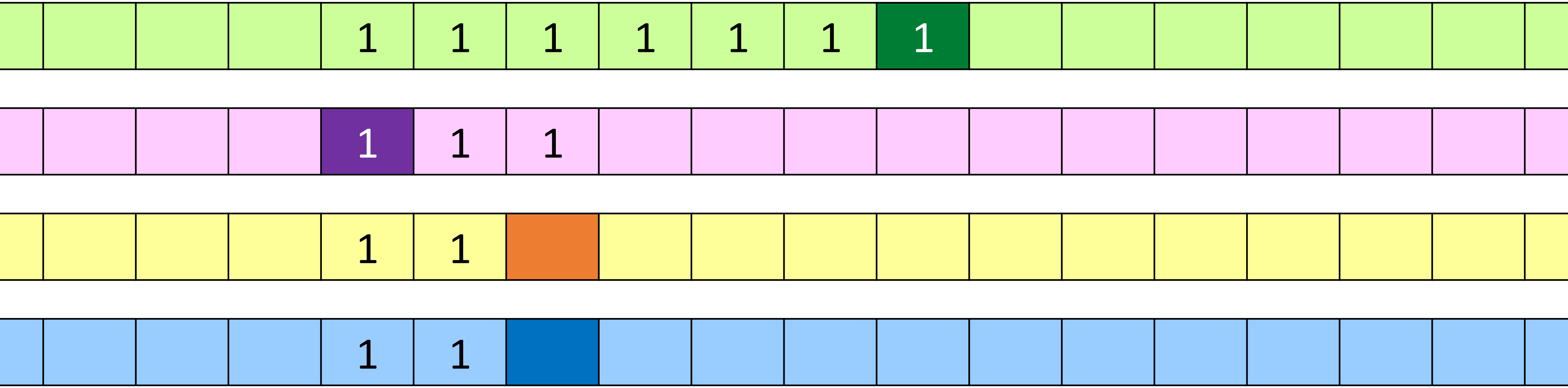


Problem 2.3 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle \mathrm{q}_2, (1,1,\square,\square), (1,1,\square,\square), q_2, (s, l, s, s) \rangle$

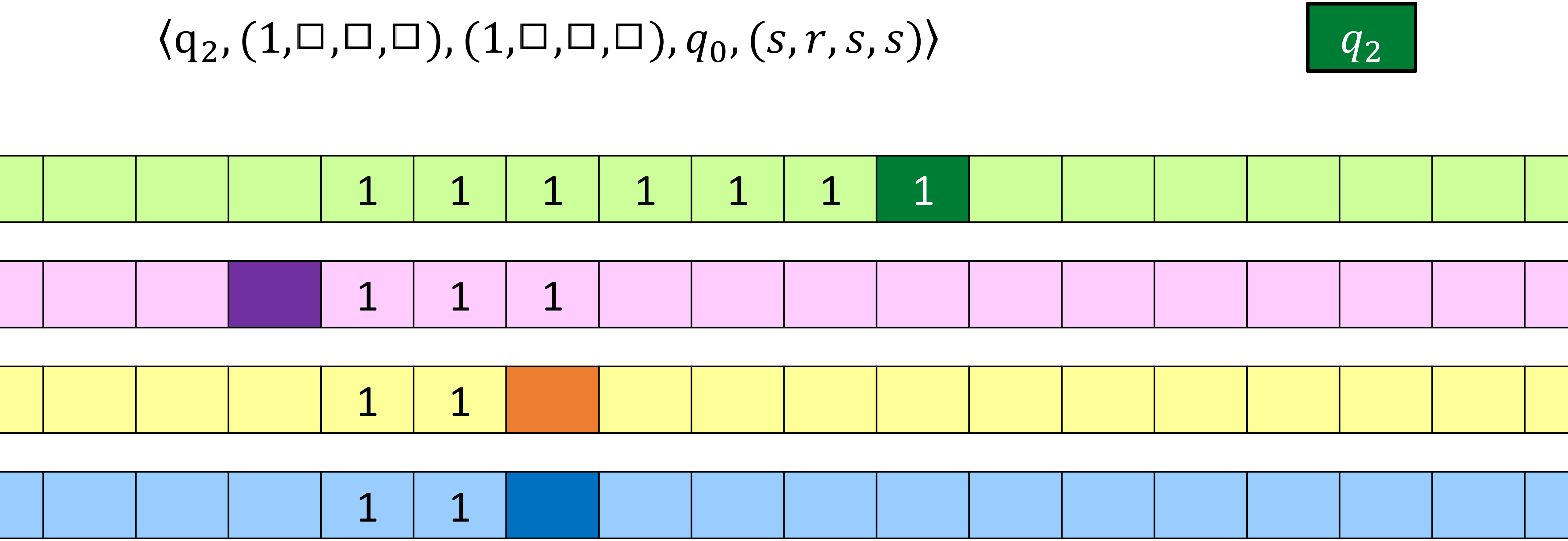
q_2



Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle \mathrm{q}_2, (1, \square, \square, \square), (1, \square, \square, \square), q_0, (s, r, s, s) \rangle$

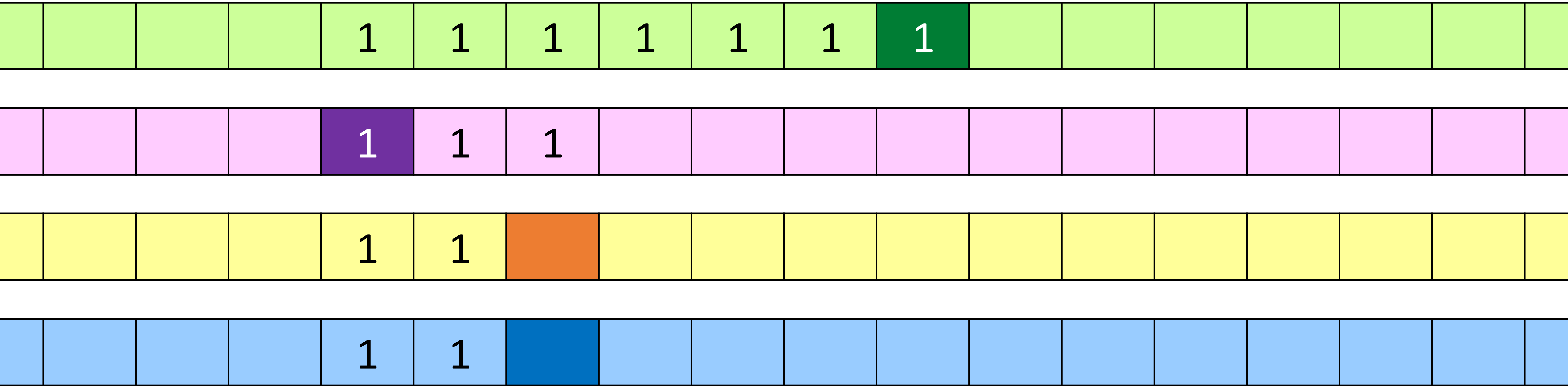


Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

$\langle q_0, (1,1,\square,\square), (1,1,1,\square), q_1, (r,r,r,s) \rangle$

q_0

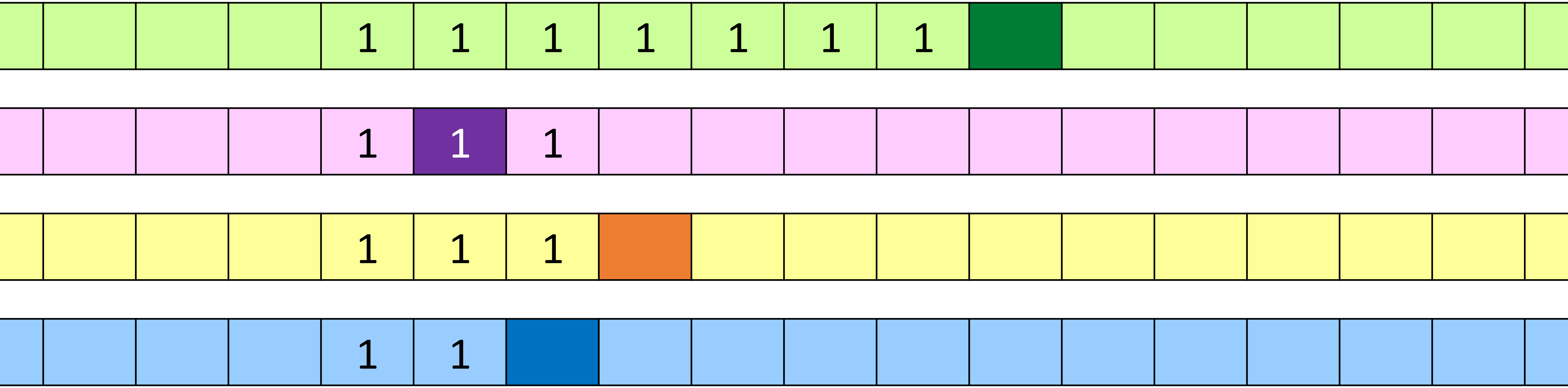


Problem 2.3 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

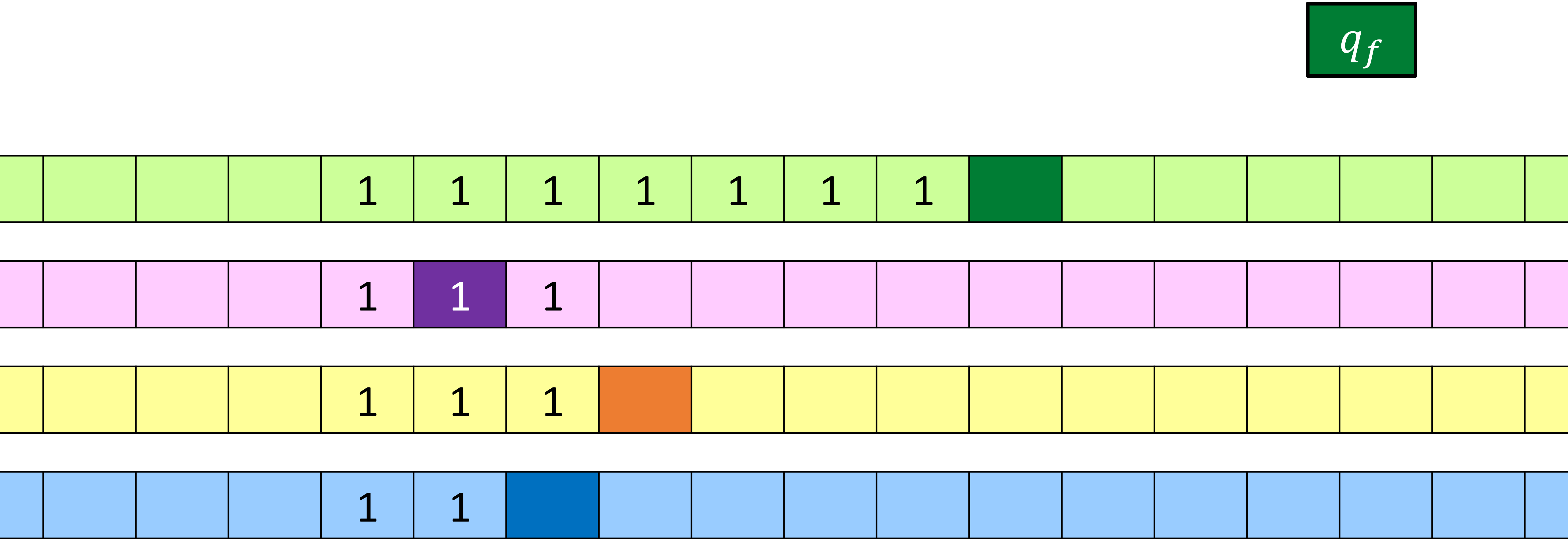
$\langle \mathrm{q}_1, (\square, 1, \square, \square), (\square, 1, \square, \square), q_f, (s, s, s, s) \rangle$

q_0



Problem 2.3 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

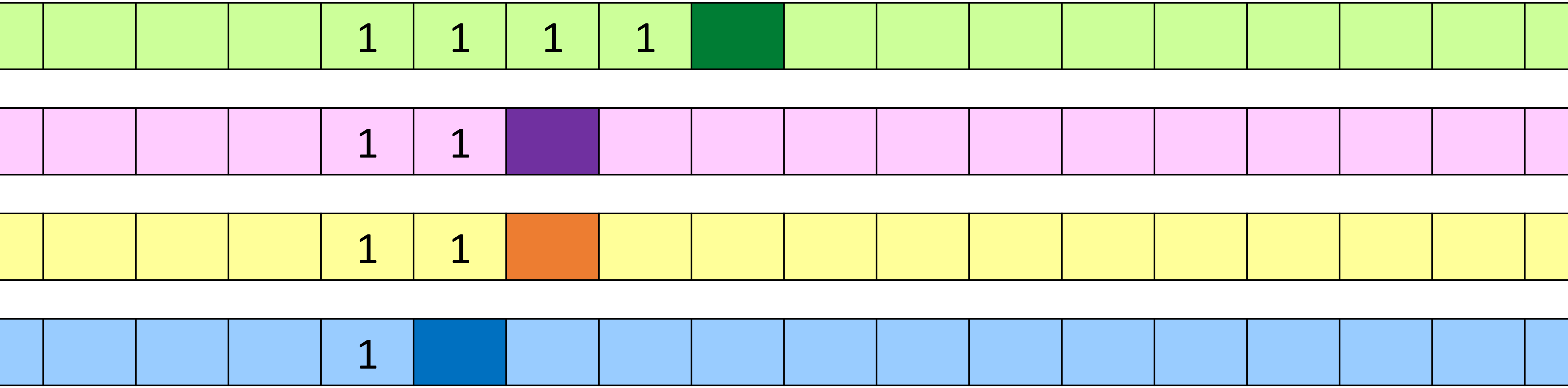


Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

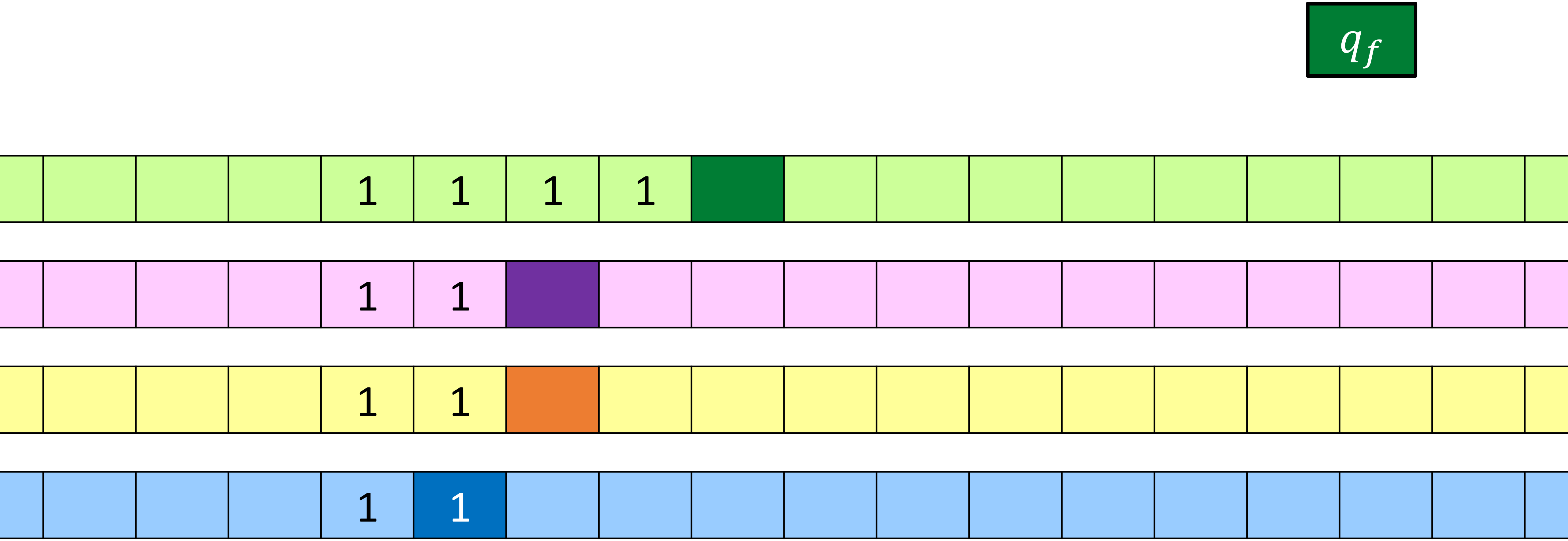
$\langle \mathrm{q}_1, (\square,\square,\square,\square), (\square,\square,\square,1), q_f, (s,s,s,s) \rangle$

q_1



Problem 2.3 from EsMacchineTuring.pdf (uniroma2.it)

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

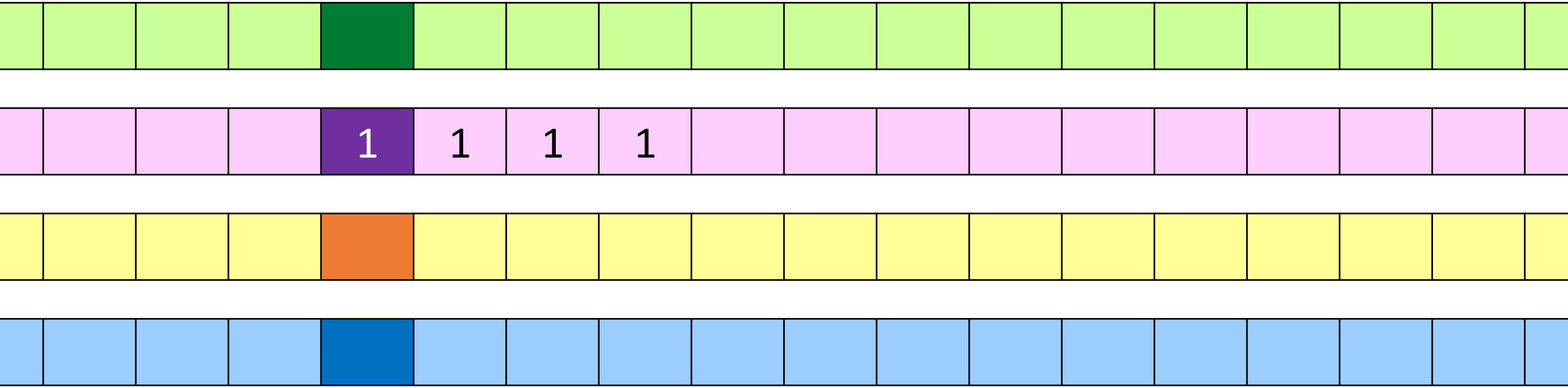


Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$

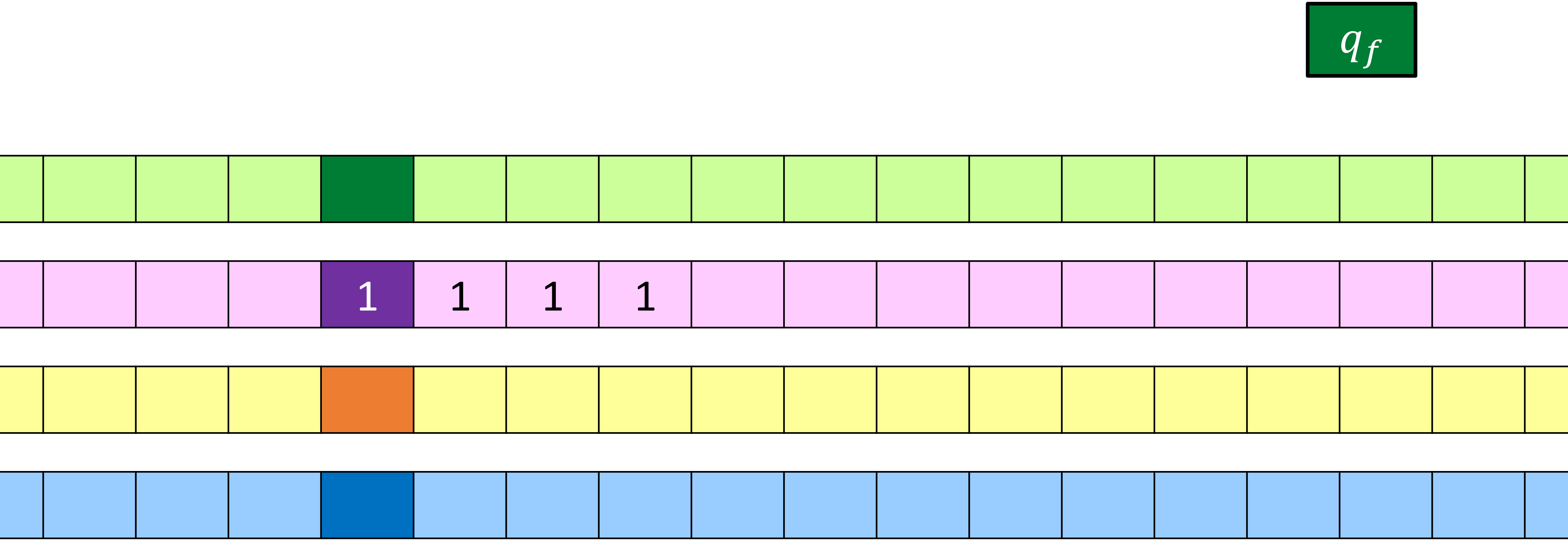
$\langle \mathrm{q}_0, (\square, 1, \square, \square), (\square, 1, \square, \square), q_f, (s, s, s, s) \rangle$

q_0



Problem 2.3 from [EsMacchineTuring.pdf (uniroma2.it)]

$$\Sigma = \{1, \square\}, Q = \{q_0, q_1, q_2, q_f\}$$



Problem 2.6 from EsMacchineTuring.pdf (uniroma2.it)

Let k be a constant in $\mathbb{N}$, and let $\boldsymbol{NT_k}$ be a non-deterministic Turing machine with a degree of non-determinism equal to $\boldsymbol{k}$. Define a non-deterministic Turing machine $\boldsymbol{NT_2}$ with a degree of non-determinism equal to 2 that is equivalent to $\boldsymbol{NT_k}$