

Question 1

Part a

- The initial value of each counter is 0.
- A counter of a frame increases its value by 1 when one page is associated with that frame.
- A counter of a frame decreases its value by 1 when 1 associated page is not required any more.
- Replace the page in the frame which has the smallest value in its counter. When there is a tie, apply the FIFO rule.

Part b

13 page faults occur for the algorithm above.

reference string:

F F F F F ✓ ✓ F F F F ✓ ✓ F ✓ ✓ ✓ F F ✓ ✓ F
 1 2 3 4 5 3 4 1 6 7 8 7 8 9 7 8 9 5 4 5 4 2

$$5 + 4 + 1 + 2 + 1 = 13$$

page frame: size 4 (first column: frame with page id; second column: counter)

empty $\xrightarrow{+4}$ $\begin{matrix} 1 & 1 \\ 2 & 1 \\ 3 & 1 \\ 4 & 1 \end{matrix}$ $\xrightarrow{+1}$ $\begin{matrix} 5 & 2 \\ 2 & 1 \\ 3 & 1 \\ 4 & 1 \end{matrix}$ $\xrightarrow{+1}$ $\begin{matrix} 5 & 2 \\ 1 & 2 \\ 3 & 1 \\ 4 & 1 \end{matrix}$ $\xrightarrow{+1}$ $\begin{matrix} 5 & 2 \\ 1 & 2 \\ 6 & 2 \\ 4 & 1 \end{matrix}$ $\xrightarrow{+1}$ $\begin{matrix} 5 & 2 \\ 1 & 2 \\ 6 & 2 \\ 7 & 2 \end{matrix}$ $\xrightarrow{+1}$ $\begin{matrix} 8 & 3 \\ 1 & 2 \\ 6 & 2 \\ 7 & 2 \end{matrix}$ $\xrightarrow{+1}$ $\begin{matrix} 8 & 3 \\ 9 & 3 \\ 6 & 2 \\ 7 & 2 \end{matrix}$ $\xrightarrow{+1}$ $\begin{matrix} 8 & 3 \\ 9 & 3 \\ 5 & 3 \\ 7 & 2 \end{matrix}$
 $\xrightarrow{+1}$ $\begin{matrix} 8 & 3 \\ 9 & 3 \\ 5 & 3 \\ 4 & 3 \end{matrix}$ $\xrightarrow{+1}$ $\begin{matrix} 2 & 4 \\ 9 & 3 \\ 5 & 3 \\ 4 & 3 \end{matrix}$

Part c

The minimum number of page faults is 11.

reference string:

F F F F F ✓ ✓ ✓ F F F ✓ ✓ F ✓ ✓ ✓ ✓ F ✓ ✓ F
 1 2 3 4 5 3 4 1 6 7 8 7 8 9 7 8 9 5 4 5 4 2

$$5 + 3 + 1 + 1 + 1 = 11$$

page frame: size 4

