

**Question 1**

a. Define a page-replacement algorithm using this basic idea. Specifically address these problems:

I. What the initial value of the counters is.

**The initial value of the counter is 0. (ZERO)**

II. When counters are increased.

**When a new page is associated with the frame, the counter is incremented.**

III. When counters are decreased.

**When an associated page with the frame is no longer required, the counter is decremented.**

iv. How the page to be replaced is selected.

**The page frame with the smallest counter is selected then replaced.**

b. How many page faults occur for your algorithm for the following reference string, for four-page frames? 1, 2, 3, 4, 5, 3, 4, 1, 6, 7, 8, 7, 8, 9, 7, 8, 9, 5, 4, 5, 4, 2.

**FIFO Replacement Algorithm: 13 Page Faults**

**LRU Replacement Algorithm: 13 Page Faults**

**FIFO Algorithm**

	1	2	3	4	5	3	4	1	6	7	8	7	8	9	7	8	9	5	4	5	4	2
Frame 1→	1	1	1	1	5	5	5	5	5	5	8	8	8	8	8	8	8	8	8	8	8	2
Frame 2→		2	2	2	2	2	2	1	1	1	1	1	1	9	9	9	9	9	9	9	9	9
Frame 3→			3	3	3	3	3	3	6	6	6	6	6	6	6	6	6	5	5	5	5	5
Frame 4→				4	4	4	4	4	4	7	7	7	7	7	7	7	7	7	4	4	4	4
	*	*	*	*	*	hit	hit	*	*	*	*	hit	hit	*	hit	hit	hit	*	*	hit	hit	*

∴ 13 page faults  
∴ 9 page hits

c. What is the minimum number of page faults for an optimal page replacement strategy for the reference string in part b with four-page frames?

**OPTIMAL Replacement Algorithm: 11 Page Faults**

**Question 2 Page Replacement Algorithm**

**Optimal Algorithm**

	1	2	3	4	5	3	4	1	6	7	8	7	8	9	7	8	9	5	4	5	4	2
Frame 1→	1	1	1	1	1	1	1	1	6	6	8	8	8	8	8	8	8	8	8	8	8	2
Frame 2→		2		2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Frame 3→			3	3	3	3	3	3	3	7	7	7	7	7	7	7	7	7	4	4	4	4
Frame 4→				4	4	4	4	4	4	4	4	4	4	9	9	9	9	9	9	9	9	9
	*	*	*	*	*	hit	hit	hit	*	*	*	hit	hit	*	hit	hit	hit	hit	*	hit	hit	*

∴ 11 page faults  
∴ 11 page hits

```

Assignment4 - Q2PageReplacementAlgorithm.c
File Edit View Navigate Code Refactor Build Run Tools VCS Window Help
Assignment4 Q2PageReplacementAlgorithm.c
Run: Assignment4
/home/mirage/CLionProjects/Assignment4/cmake-build-debug/Assignment4
Enter the number of pages: 22
Enter the number of page reference strings: 1 2 3 4 5 3 4 1 6 7 8 7 8 9 7 8 9 5 4 5 4 2
Enter the size of the page frame: 4
Number of pages: 22; Reference Strings: 1 2 3 4 5 3 4 1 6 7 8 7 8 9 7 8 9 5 4 5 4 2; Frame size: 4;

```

```

Q2PageReplacementAlgorithm.c
Run: Assignment4
Number of pages: 22; Reference Strings: 1 2 3 4 5 3 4 1 6 7 8 7 8 9 7 8 9 5 4 5 4 2; Frame size: 4;

[MENU]

1) FIFO
2) LRU
3) QUIT

Enter your choice 1 or 2: 1

1 -1 -1 -1
1 2 -1 -1
1 2 3 -1
1 2 3 4
5 2 3 4
5 2 3 4
5 2 3 4
5 1 3 4
5 1 6 4
5 1 6 7
8 1 6 7
8 1 6 7
8 1 6 7
8 9 6 7
8 9 6 7
8 9 6 7
8 9 6 7
8 9 5 7
8 9 5 4
8 9 5 4
8 9 5 4
8 9 5 4
8 9 5 4
2 9 5 4

#Page Faults: 13

```

```
#Page Faults: 13
```

```
[MENU]
```

```
1) FIFO
```

```
2) LRU
```

```
3) QUIT
```

```
Enter your choice 1 or 2: 2
```

```
1  -1 -1 -1
```

```
1  2  -1 -1
```

```
1  2  3  -1
```

```
1  2  3  4
```

```
5  2  3  4
```

```
5  2  3  4
```

```
5  2  3  4
```

```
5  1  3  4
```

```
6  1  3  4
```

```
6  1  7  4
```

```
6  1  7  8
```

```
6  1  7  8
```

```
6  1  7  8
```

```
6  9  7  8
```

```
6  9  7  8
```

```
6  9  7  8
```

```
6  9  7  8
```

```
5  9  7  8
```

```
5  9  4  8
```

```
5  9  4  8
```

```
5  9  4  8
```

```
5  9  4  2
```

```
#Page Faults: 13
```

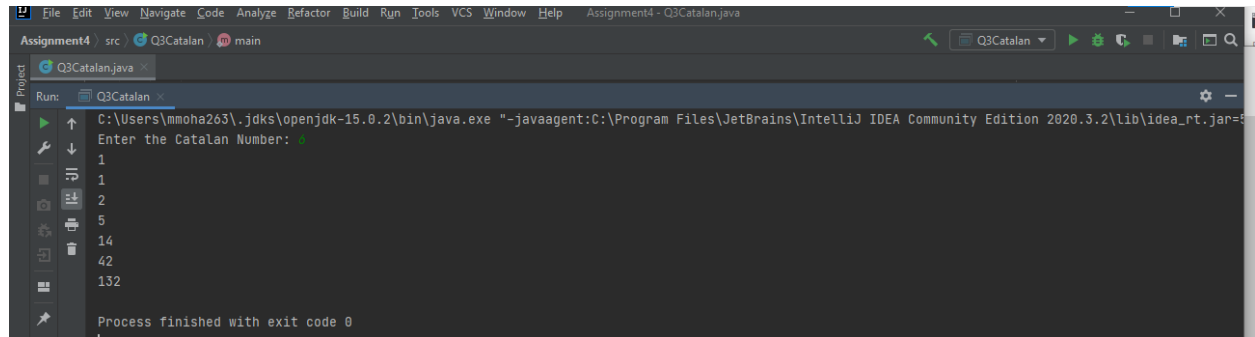
```
#Page Faults: 13
[MENU]

1) FIFO
2) LRU
3) QUIT

Enter your choice 1 or 2: 3

Process finished with exit code 0
```

### Question 3 – Catalan Number



The screenshot shows the IntelliJ IDEA interface with a project named 'Assignment4'. The 'Run' window displays the execution of 'Q3Catalan.java'. The command line shows the Java executable path and the main method. The input is 'Enter the Catalan Number: 3'. The output shows the sequence of Catalan numbers: 1, 1, 2, 5, 14, 42, 132. The process finished with exit code 0.

```
Run: Q3Catalan
C:\Users\mmoha263\.jdk\openjdk-15.0.2\bin\java.exe --javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2020.3.2\lib\idea_rt.jar=
Enter the Catalan Number: 3
1
1
2
5
14
42
132
Process finished with exit code 0
```