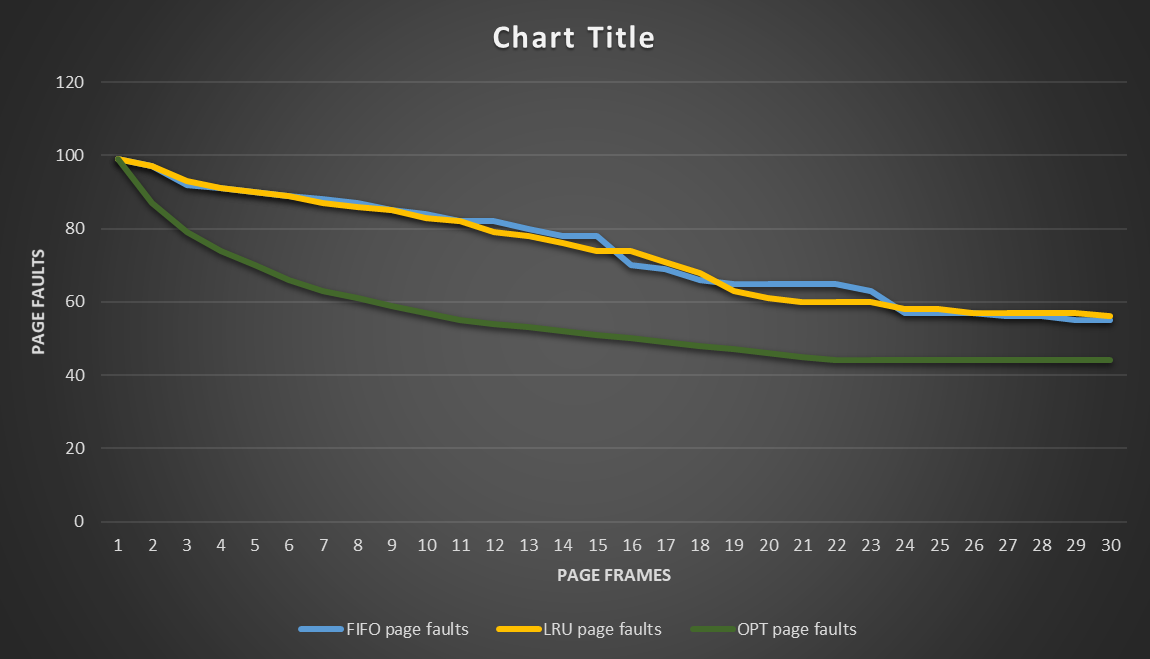
Project 2

Overview: In this project we implemented the three main algorithms for page replacement. These were FIFO, LRU, and OPT. We gave the three different methods a randomly generated page-reference string to interpret and simulate the page frames being loaded with page references. Once, the reference string was generated results were recorder for each simulation where the page frame capacity was increased from 1 to 30. Bellow are the results of the total page faults for each of the page replacement methods with the following randomly generated reference string:

* Reference string length: 100 references
* String: 10 23 15 46 44 41 29 40 32 49 28 25 21 17 10 29 19 49 14 34 19 35 29 45 45 21 24 36 13 9 6 23 32 24 19 28 15 48 21 49 48 49 26 21 18 38 0 38 40 16 24 9 3 5 6 1 27 30 37 40 39 46 14 21 22 35 2 39 36 23 39 36 24 17 9 42 6 9 30 46 27 4 7 30 10 13 31 39 43 21 29 34 19 45 7 41 31 9 30 17



As you can see the LRU and the FIFO page replacement methods have very similar results for page faults. LRU works similar to the FIFO method. While the method OPT checks the rest of the page reference string and compares the existing page frames to decided which page frames should be replaced

# Summary - FIFO algorithm

A FIFO replacement algorithm associates with each page the time when that page was brought into memory. When a page must be replaced, the oldest page is chosen.

Solution visualization

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **t** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| **ref** |  | **10** | **23** | **15** | **46** | **44** | **41** | **29** | **40** | **32** | **49** | **28** | **25** | **21** | **17** | **10** | **29** | **19** | **49** | **14** | **34** | **19** | **35** | **29** | **45** | **45** | **21** | **24** | **36** | **13** |
| **f** |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 25 | 21 | 17 | 17 | 17 | 19 | 19 | 14 | 34 | 34 | 35 | 35 | 45 | 45 | 45 | 24 | 36 | 13 |
| **f** |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 25 | 21 | 21 | 21 | 17 | 17 | 19 | 14 | 14 | 34 | 34 | 35 | 35 | 35 | 45 | 24 | 36 |
| **f** |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 25 | 25 | 25 | 21 | 21 | 17 | 19 | 19 | 14 | 14 | 34 | 34 | 34 | 35 | 45 | 24 |
| **f** |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 28 | 28 | 25 | 25 | 21 | 17 | 17 | 19 | 19 | 14 | 14 | 14 | 34 | 35 | 45 |
| **f** |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 49 | 49 | 28 | 28 | 25 | 21 | 21 | 17 | 17 | 19 | 19 | 19 | 14 | 34 | 35 |
| **f** |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 32 | 32 | 49 | 49 | 28 | 25 | 25 | 21 | 21 | 17 | 17 | 17 | 19 | 14 | 34 |
| **f** |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 40 | 40 | 32 | 32 | 49 | 28 | 28 | 25 | 25 | 21 | 21 | 21 | 17 | 19 | 14 |
| **f** |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 29 | 29 | 40 | 40 | 32 | 49 | 49 | 28 | 28 | 25 | 25 | 25 | 21 | 17 | 19 |
| **f** |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 41 | 41 | 29 | 29 | 40 | 32 | 32 | 49 | 49 | 28 | 28 | 28 | 25 | 21 | 17 |
| **f** |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 44 | 44 | 41 | 41 | 29 | 40 | 40 | 32 | 32 | 49 | 49 | 49 | 28 | 25 | 21 |
| **f** |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 46 | 46 | 44 | 44 | 41 | 29 | 29 | 40 | 40 | 32 | 32 | 32 | 49 | 28 | 25 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 15 | 15 | 46 | 46 | 44 | 41 | 41 | 29 | 29 | 40 | 40 | 40 | 32 | 49 | 28 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 23 | 23 | 15 | 15 | 46 | 44 | 44 | 41 | 41 | 29 | 29 | 29 | 40 | 32 | 49 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 10 | 23 | 23 | 15 | 46 | 46 | 44 | 44 | 41 | 41 | 41 | 29 | 40 | 32 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 23 | 15 | 15 | 46 | 46 | 44 | 44 | 44 | 41 | 29 | 40 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 23 | 15 | 15 | 46 | 46 | 46 | 44 | 41 | 29 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 23 | 23 | 15 | 15 | 15 | 46 | 44 | 41 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 23 | 23 | 23 | 15 | 46 | 44 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 10 | 23 | 15 | 46 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **hit** |  | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✓ | ✓ | ✗ | ✓ | ✗ | ✗ | ✓ | ✗ | ✓ | ✗ | ✓ | ✓ | ✗ | ✗ | ✗ |
| **v** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **t** | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 |
| **ref** | **9** | **6** | **23** | **32** | **24** | **19** | **28** | **15** | **48** | **21** | **49** | **48** | **49** | **26** | **21** | **18** | **38** | **0** | **38** | **40** | **16** | **24** | **9** | **3** | **5** | **6** | **1** | **27** | **30** | **37** |
| **f** | 9 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 48 | 48 | 48 | 48 | 48 | 26 | 26 | 18 | 38 | 0 | 0 | 0 | 16 | 16 | 16 | 3 | 5 | 5 | 1 | 27 | 30 | 37 |
| **f** | 13 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 6 | 6 | 6 | 6 | 6 | 48 | 48 | 26 | 18 | 38 | 38 | 38 | 0 | 0 | 0 | 16 | 3 | 3 | 5 | 1 | 27 | 30 |
| **f** | 36 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 9 | 9 | 9 | 9 | 9 | 6 | 6 | 48 | 26 | 18 | 18 | 18 | 38 | 38 | 38 | 0 | 16 | 16 | 3 | 5 | 1 | 27 |
| **f** | 24 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 13 | 13 | 13 | 13 | 13 | 9 | 9 | 6 | 48 | 26 | 26 | 26 | 18 | 18 | 18 | 38 | 0 | 0 | 16 | 3 | 5 | 1 |
| **f** | 45 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 36 | 36 | 36 | 36 | 36 | 13 | 13 | 9 | 6 | 48 | 48 | 48 | 26 | 26 | 26 | 18 | 38 | 38 | 0 | 16 | 3 | 5 |
| **f** | 35 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 24 | 24 | 24 | 24 | 24 | 36 | 36 | 13 | 9 | 6 | 6 | 6 | 48 | 48 | 48 | 26 | 18 | 18 | 38 | 0 | 16 | 3 |
| **f** | 34 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 45 | 45 | 45 | 45 | 45 | 24 | 24 | 36 | 13 | 9 | 9 | 9 | 6 | 6 | 6 | 48 | 26 | 26 | 18 | 38 | 0 | 16 |
| **f** | 14 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 35 | 35 | 35 | 35 | 35 | 45 | 45 | 24 | 36 | 13 | 13 | 13 | 9 | 9 | 9 | 6 | 48 | 48 | 26 | 18 | 38 | 0 |
| **f** | 19 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 34 | 34 | 34 | 34 | 34 | 35 | 35 | 45 | 24 | 36 | 36 | 36 | 13 | 13 | 13 | 9 | 6 | 6 | 48 | 26 | 18 | 38 |
| **f** | 17 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 14 | 14 | 14 | 14 | 14 | 34 | 34 | 35 | 45 | 24 | 24 | 24 | 36 | 36 | 36 | 13 | 9 | 9 | 6 | 48 | 26 | 18 |
| **f** | 21 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 19 | 19 | 19 | 19 | 19 | 14 | 14 | 34 | 35 | 45 | 45 | 45 | 24 | 24 | 24 | 36 | 13 | 13 | 9 | 6 | 48 | 26 |
| **f** | 25 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 17 | 17 | 17 | 17 | 17 | 19 | 19 | 14 | 34 | 35 | 35 | 35 | 45 | 45 | 45 | 24 | 36 | 36 | 13 | 9 | 6 | 48 |
| **f** | 28 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 21 | 21 | 21 | 21 | 21 | 17 | 17 | 19 | 14 | 34 | 34 | 34 | 35 | 35 | 35 | 45 | 24 | 24 | 36 | 13 | 9 | 6 |
| **f** | 49 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 25 | 25 | 25 | 25 | 25 | 21 | 21 | 17 | 19 | 14 | 14 | 14 | 34 | 34 | 34 | 35 | 45 | 45 | 24 | 36 | 13 | 9 |
| **f** | 32 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 28 | 28 | 28 | 28 | 28 | 25 | 25 | 21 | 17 | 19 | 19 | 19 | 14 | 14 | 14 | 34 | 35 | 35 | 45 | 24 | 36 | 13 |
| **f** | 40 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 49 | 49 | 49 | 49 | 49 | 28 | 28 | 25 | 21 | 17 | 17 | 17 | 19 | 19 | 19 | 14 | 34 | 34 | 35 | 45 | 24 | 36 |
| **f** | 29 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 32 | 32 | 32 | 32 | 32 | 49 | 49 | 28 | 25 | 21 | 21 | 21 | 17 | 17 | 17 | 19 | 14 | 14 | 34 | 35 | 45 | 24 |
| **f** | 41 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 40 | 40 | 40 | 40 | 40 | 32 | 32 | 49 | 28 | 25 | 25 | 25 | 21 | 21 | 21 | 17 | 19 | 19 | 14 | 34 | 35 | 45 |
| **f** | 44 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 29 | 29 | 29 | 29 | 29 | 40 | 40 | 32 | 49 | 28 | 28 | 28 | 25 | 25 | 25 | 21 | 17 | 17 | 19 | 14 | 34 | 35 |
| **f** | 46 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 41 | 41 | 41 | 41 | 41 | 29 | 29 | 40 | 32 | 49 | 49 | 49 | 28 | 28 | 28 | 25 | 21 | 21 | 17 | 19 | 14 | 34 |
| **f** | 15 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 44 | 44 | 44 | 44 | 44 | 41 | 41 | 29 | 40 | 32 | 32 | 32 | 49 | 49 | 49 | 28 | 25 | 25 | 21 | 17 | 19 | 14 |
| **f** | 23 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 46 | 46 | 46 | 46 | 46 | 44 | 44 | 41 | 29 | 40 | 40 | 40 | 32 | 32 | 32 | 49 | 28 | 28 | 25 | 21 | 17 | 19 |
| **f** | 10 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 15 | 15 | 15 | 15 | 15 | 46 | 46 | 44 | 41 | 29 | 29 | 29 | 40 | 40 | 40 | 32 | 49 | 49 | 28 | 25 | 21 | 17 |
| **f** |  | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 23 | 23 | 23 | 23 | 23 | 15 | 15 | 46 | 44 | 41 | 41 | 41 | 29 | 29 | 29 | 40 | 32 | 32 | 49 | 28 | 25 | 21 |
| **f** |  |  |  |  |  |  |  |  | 10 | 10 | 10 | 10 | 10 | 23 | 23 | 15 | 46 | 44 | 44 | 44 | 41 | 41 | 41 | 29 | 40 | 40 | 32 | 49 | 28 | 25 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 23 | 15 | 46 | 46 | 46 | 44 | 44 | 44 | 41 | 29 | 29 | 40 | 32 | 49 | 28 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 15 | 15 | 46 | 46 | 46 | 44 | 41 | 41 | 29 | 40 | 32 | 49 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 23 | 23 | 15 | 15 | 15 | 46 | 44 | 44 | 41 | 29 | 40 | 32 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 10 | 23 | 23 | 23 | 15 | 46 | 46 | 44 | 41 | 29 | 40 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 10 | 23 | 15 | 15 | 46 | 44 | 41 | 29 |
| **hit** | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✗ | ✗ | ✗ | ✓ | ✓ | ✗ | ✓ | ✓ | ✗ | ✗ | ✓ | ✗ | ✗ | ✗ | ✗ |
| **v** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 |  | 15 | 46 | 44 | 41 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **t** | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 |
| **ref** | **40** | **39** | **46** | **14** | **21** | **22** | **35** | **2** | **39** | **36** | **23** | **39** | **36** | **24** | **17** | **9** | **42** | **6** | **9** | **30** | **46** | **27** | **4** | **7** | **30** | **10** | **13** | **31** | **39** | **43** |
| **f** | 37 | 39 | 46 | 46 | 46 | 22 | 22 | 2 | 2 | 2 | 23 | 23 | 23 | 23 | 23 | 23 | 42 | 42 | 42 | 42 | 42 | 42 | 4 | 7 | 7 | 10 | 10 | 31 | 31 | 43 |
| **f** | 30 | 37 | 39 | 39 | 39 | 46 | 46 | 22 | 22 | 22 | 2 | 2 | 2 | 2 | 2 | 2 | 23 | 23 | 23 | 23 | 23 | 23 | 42 | 4 | 4 | 7 | 7 | 10 | 10 | 31 |
| **f** | 27 | 30 | 37 | 37 | 37 | 39 | 39 | 46 | 46 | 46 | 22 | 22 | 22 | 22 | 22 | 22 | 2 | 2 | 2 | 2 | 2 | 2 | 23 | 42 | 42 | 4 | 4 | 7 | 7 | 10 |
| **f** | 1 | 27 | 30 | 30 | 30 | 37 | 37 | 39 | 39 | 39 | 46 | 46 | 46 | 46 | 46 | 46 | 22 | 22 | 22 | 22 | 22 | 22 | 2 | 23 | 23 | 42 | 42 | 4 | 4 | 7 |
| **f** | 5 | 1 | 27 | 27 | 27 | 30 | 30 | 37 | 37 | 37 | 39 | 39 | 39 | 39 | 39 | 39 | 46 | 46 | 46 | 46 | 46 | 46 | 22 | 2 | 2 | 23 | 23 | 42 | 42 | 4 |
| **f** | 3 | 5 | 1 | 1 | 1 | 27 | 27 | 30 | 30 | 30 | 37 | 37 | 37 | 37 | 37 | 37 | 39 | 39 | 39 | 39 | 39 | 39 | 46 | 22 | 22 | 2 | 2 | 23 | 23 | 42 |
| **f** | 16 | 3 | 5 | 5 | 5 | 1 | 1 | 27 | 27 | 27 | 30 | 30 | 30 | 30 | 30 | 30 | 37 | 37 | 37 | 37 | 37 | 37 | 39 | 46 | 46 | 22 | 22 | 2 | 2 | 23 |
| **f** | 0 | 16 | 3 | 3 | 3 | 5 | 5 | 1 | 1 | 1 | 27 | 27 | 27 | 27 | 27 | 27 | 30 | 30 | 30 | 30 | 30 | 30 | 37 | 39 | 39 | 46 | 46 | 22 | 22 | 2 |
| **f** | 38 | 0 | 16 | 16 | 16 | 3 | 3 | 5 | 5 | 5 | 1 | 1 | 1 | 1 | 1 | 1 | 27 | 27 | 27 | 27 | 27 | 27 | 30 | 37 | 37 | 39 | 39 | 46 | 46 | 22 |
| **f** | 18 | 38 | 0 | 0 | 0 | 16 | 16 | 3 | 3 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 1 | 1 | 1 | 1 | 1 | 1 | 27 | 30 | 30 | 37 | 37 | 39 | 39 | 46 |
| **f** | 26 | 18 | 38 | 38 | 38 | 0 | 0 | 16 | 16 | 16 | 3 | 3 | 3 | 3 | 3 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 1 | 27 | 27 | 30 | 30 | 37 | 37 | 39 |
| **f** | 48 | 26 | 18 | 18 | 18 | 38 | 38 | 0 | 0 | 0 | 16 | 16 | 16 | 16 | 16 | 16 | 3 | 3 | 3 | 3 | 3 | 3 | 5 | 1 | 1 | 27 | 27 | 30 | 30 | 37 |
| **f** | 6 | 48 | 26 | 26 | 26 | 18 | 18 | 38 | 38 | 38 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 16 | 16 | 16 | 16 | 16 | 3 | 5 | 5 | 1 | 1 | 27 | 27 | 30 |
| **f** | 9 | 6 | 48 | 48 | 48 | 26 | 26 | 18 | 18 | 18 | 38 | 38 | 38 | 38 | 38 | 38 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 3 | 3 | 5 | 5 | 1 | 1 | 27 |
| **f** | 13 | 9 | 6 | 6 | 6 | 48 | 48 | 26 | 26 | 26 | 18 | 18 | 18 | 18 | 18 | 18 | 38 | 38 | 38 | 38 | 38 | 38 | 0 | 16 | 16 | 3 | 3 | 5 | 5 | 1 |
| **f** | 36 | 13 | 9 | 9 | 9 | 6 | 6 | 48 | 48 | 48 | 26 | 26 | 26 | 26 | 26 | 26 | 18 | 18 | 18 | 18 | 18 | 18 | 38 | 0 | 0 | 16 | 16 | 3 | 3 | 5 |
| **f** | 24 | 36 | 13 | 13 | 13 | 9 | 9 | 6 | 6 | 6 | 48 | 48 | 48 | 48 | 48 | 48 | 26 | 26 | 26 | 26 | 26 | 26 | 18 | 38 | 38 | 0 | 0 | 16 | 16 | 3 |
| **f** | 45 | 24 | 36 | 36 | 36 | 13 | 13 | 9 | 9 | 9 | 6 | 6 | 6 | 6 | 6 | 6 | 48 | 48 | 48 | 48 | 48 | 48 | 26 | 18 | 18 | 38 | 38 | 0 | 0 | 16 |
| **f** | 35 | 45 | 24 | 24 | 24 | 36 | 36 | 13 | 13 | 13 | 9 | 9 | 9 | 9 | 9 | 9 | 6 | 6 | 6 | 6 | 6 | 6 | 48 | 26 | 26 | 18 | 18 | 38 | 38 | 0 |
| **f** | 34 | 35 | 45 | 45 | 45 | 24 | 24 | 36 | 36 | 36 | 13 | 13 | 13 | 13 | 13 | 13 | 9 | 9 | 9 | 9 | 9 | 9 | 6 | 48 | 48 | 26 | 26 | 18 | 18 | 38 |
| **f** | 14 | 34 | 35 | 35 | 35 | 45 | 45 | 24 | 24 | 24 | 36 | 36 | 36 | 36 | 36 | 36 | 13 | 13 | 13 | 13 | 13 | 13 | 9 | 6 | 6 | 48 | 48 | 26 | 26 | 18 |
| **f** | 19 | 14 | 34 | 34 | 34 | 35 | 35 | 45 | 45 | 45 | 24 | 24 | 24 | 24 | 24 | 24 | 36 | 36 | 36 | 36 | 36 | 36 | 13 | 9 | 9 | 6 | 6 | 48 | 48 | 26 |
| **f** | 17 | 19 | 14 | 14 | 14 | 34 | 34 | 35 | 35 | 35 | 45 | 45 | 45 | 45 | 45 | 45 | 24 | 24 | 24 | 24 | 24 | 24 | 36 | 13 | 13 | 9 | 9 | 6 | 6 | 48 |
| **f** | 21 | 17 | 19 | 19 | 19 | 14 | 14 | 34 | 34 | 34 | 35 | 35 | 35 | 35 | 35 | 35 | 45 | 45 | 45 | 45 | 45 | 45 | 24 | 36 | 36 | 13 | 13 | 9 | 9 | 6 |
| **f** | 25 | 21 | 17 | 17 | 17 | 19 | 19 | 14 | 14 | 14 | 34 | 34 | 34 | 34 | 34 | 34 | 35 | 35 | 35 | 35 | 35 | 35 | 45 | 24 | 24 | 36 | 36 | 13 | 13 | 9 |
| **f** | 28 | 25 | 21 | 21 | 21 | 17 | 17 | 19 | 19 | 19 | 14 | 14 | 14 | 14 | 14 | 14 | 34 | 34 | 34 | 34 | 34 | 34 | 35 | 45 | 45 | 24 | 24 | 36 | 36 | 13 |
| **f** | 49 | 28 | 25 | 25 | 25 | 21 | 21 | 17 | 17 | 17 | 19 | 19 | 19 | 19 | 19 | 19 | 14 | 14 | 14 | 14 | 14 | 14 | 34 | 35 | 35 | 45 | 45 | 24 | 24 | 36 |
| **f** | 32 | 49 | 28 | 28 | 28 | 25 | 25 | 21 | 21 | 21 | 17 | 17 | 17 | 17 | 17 | 17 | 19 | 19 | 19 | 19 | 19 | 19 | 14 | 34 | 34 | 35 | 35 | 45 | 45 | 24 |
| **f** | 40 | 32 | 49 | 49 | 49 | 28 | 28 | 25 | 25 | 25 | 21 | 21 | 21 | 21 | 21 | 21 | 17 | 17 | 17 | 17 | 17 | 17 | 19 | 14 | 14 | 34 | 34 | 35 | 35 | 45 |
| **f** | 29 | 40 | 32 | 32 | 32 | 49 | 49 | 28 | 28 | 28 | 25 | 25 | 25 | 25 | 25 | 25 | 21 | 21 | 21 | 21 | 21 | 21 | 17 | 19 | 19 | 14 | 14 | 34 | 34 | 35 |
| **hit** | ✓ | ✗ | ✗ | ✓ | ✓ | ✗ | ✓ | ✗ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✓ | ✗ | ✓ | ✗ | ✓ | ✗ |
| **v** |  | 29 | 40 |  |  | 32 |  | 49 |  |  | 28 |  |  |  |  |  | 25 |  |  |  |  |  | 21 | 17 |  | 19 |  | 14 |  | 34 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **t** | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **ref** | **21** | **29** | **34** | **19** | **45** | **7** | **41** | **31** | **9** | **30** | **17** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** | 21 | 29 | 34 | 19 | 45 | 45 | 41 | 41 | 9 | 9 | 17 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 43 | 21 | 29 | 34 | 19 | 19 | 45 | 45 | 41 | 41 | 9 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 31 | 43 | 21 | 29 | 34 | 34 | 19 | 19 | 45 | 45 | 41 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 10 | 31 | 43 | 21 | 29 | 29 | 34 | 34 | 19 | 19 | 45 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 7 | 10 | 31 | 43 | 21 | 21 | 29 | 29 | 34 | 34 | 19 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 4 | 7 | 10 | 31 | 43 | 43 | 21 | 21 | 29 | 29 | 34 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 42 | 4 | 7 | 10 | 31 | 31 | 43 | 43 | 21 | 21 | 29 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 23 | 42 | 4 | 7 | 10 | 10 | 31 | 31 | 43 | 43 | 21 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 2 | 23 | 42 | 4 | 7 | 7 | 10 | 10 | 31 | 31 | 43 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 22 | 2 | 23 | 42 | 4 | 4 | 7 | 7 | 10 | 10 | 31 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 46 | 22 | 2 | 23 | 42 | 42 | 4 | 4 | 7 | 7 | 10 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 39 | 46 | 22 | 2 | 23 | 23 | 42 | 42 | 4 | 4 | 7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 37 | 39 | 46 | 22 | 2 | 2 | 23 | 23 | 42 | 42 | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 30 | 37 | 39 | 46 | 22 | 22 | 2 | 2 | 23 | 23 | 42 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 27 | 30 | 37 | 39 | 46 | 46 | 22 | 22 | 2 | 2 | 23 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 1 | 27 | 30 | 37 | 39 | 39 | 46 | 46 | 22 | 22 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 5 | 1 | 27 | 30 | 37 | 37 | 39 | 39 | 46 | 46 | 22 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 3 | 5 | 1 | 27 | 30 | 30 | 37 | 37 | 39 | 39 | 46 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 16 | 3 | 5 | 1 | 27 | 27 | 30 | 30 | 37 | 37 | 39 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 0 | 16 | 3 | 5 | 1 | 1 | 27 | 27 | 30 | 30 | 37 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 38 | 0 | 16 | 3 | 5 | 5 | 1 | 1 | 27 | 27 | 30 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 18 | 38 | 0 | 16 | 3 | 3 | 5 | 5 | 1 | 1 | 27 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 26 | 18 | 38 | 0 | 16 | 16 | 3 | 3 | 5 | 5 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 48 | 26 | 18 | 38 | 0 | 0 | 16 | 16 | 3 | 3 | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 6 | 48 | 26 | 18 | 38 | 38 | 0 | 0 | 16 | 16 | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 9 | 6 | 48 | 26 | 18 | 18 | 38 | 38 | 0 | 0 | 16 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 13 | 9 | 6 | 48 | 26 | 26 | 18 | 18 | 38 | 38 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 36 | 13 | 9 | 6 | 48 | 48 | 26 | 26 | 18 | 18 | 38 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 24 | 36 | 13 | 9 | 6 | 6 | 48 | 48 | 26 | 26 | 18 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 45 | 24 | 36 | 13 | 9 | 9 | 6 | 6 | 48 | 48 | 26 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **hit** | ✗ | ✗ | ✗ | ✗ | ✗ | ✓ | ✗ | ✓ | ✗ | ✓ | ✗ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **v** | 35 | 45 | 24 | 36 | 13 |  | 9 |  | 6 |  | 48 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

* Total references: 100
* Total distinct references: 44
* Hits: 45
* Faults: 55
* **Hit rate:** 45/100 = **45**%
* **Fault rate:** 55/100 = **55**%

# Summary - LRU algorithm

In general, an algorithm that selects the item that has been used least recently. In memory management, selecting the page that has not been accessed in the longest time.

Solution visualization

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **t** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| **ref** |  | **10** | **23** | **15** | **46** | **44** | **41** | **29** | **40** | **32** | **49** | **28** | **25** | **21** | **17** | **10** | **29** | **19** | **49** | **14** | **34** | **19** | **35** | **29** | **45** | **45** | **21** | **24** | **36** | **13** |
| **f** |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 25 | 21 | 17 | 10 | 29 | 19 | 49 | 14 | 34 | 19 | 35 | 29 | 45 | 45 | 21 | 24 | 36 | 13 |
| **f** |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 25 | 21 | 17 | 10 | 29 | 19 | 49 | 14 | 34 | 19 | 35 | 29 | 29 | 45 | 21 | 24 | 36 |
| **f** |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 25 | 21 | 17 | 10 | 29 | 19 | 49 | 14 | 34 | 19 | 35 | 35 | 29 | 45 | 21 | 24 |
| **f** |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 25 | 21 | 17 | 10 | 29 | 19 | 49 | 14 | 34 | 19 | 19 | 35 | 29 | 45 | 21 |
| **f** |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 25 | 21 | 17 | 10 | 29 | 29 | 49 | 14 | 34 | 34 | 19 | 35 | 29 | 45 |
| **f** |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 25 | 21 | 17 | 10 | 10 | 29 | 49 | 14 | 14 | 34 | 19 | 35 | 29 |
| **f** |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 25 | 21 | 17 | 17 | 10 | 10 | 49 | 49 | 14 | 34 | 19 | 35 |
| **f** |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 25 | 21 | 21 | 17 | 17 | 10 | 10 | 49 | 14 | 34 | 19 |
| **f** |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 32 | 28 | 25 | 25 | 21 | 21 | 17 | 17 | 10 | 49 | 14 | 34 |
| **f** |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 41 | 40 | 40 | 32 | 28 | 28 | 25 | 25 | 21 | 21 | 17 | 10 | 49 | 14 |
| **f** |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 44 | 41 | 41 | 40 | 32 | 32 | 28 | 28 | 25 | 25 | 25 | 17 | 10 | 49 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 46 | 44 | 44 | 41 | 40 | 40 | 32 | 32 | 28 | 28 | 28 | 25 | 17 | 10 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 15 | 46 | 46 | 44 | 41 | 41 | 40 | 40 | 32 | 32 | 32 | 28 | 25 | 17 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 23 | 15 | 15 | 46 | 44 | 44 | 41 | 41 | 40 | 40 | 40 | 32 | 28 | 25 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 23 | 23 | 15 | 46 | 46 | 44 | 44 | 41 | 41 | 41 | 40 | 32 | 28 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 23 | 15 | 15 | 46 | 46 | 44 | 44 | 44 | 41 | 40 | 32 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 23 | 23 | 15 | 15 | 46 | 46 | 46 | 44 | 41 | 40 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 23 | 23 | 15 | 15 | 15 | 46 | 44 | 41 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 23 | 23 | 23 | 15 | 46 | 44 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 23 | 15 | 46 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 23 | 15 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 23 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **hit** |  | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✓ | ✓ | ✗ | ✓ | ✗ | ✗ | ✓ | ✗ | ✓ | ✗ | ✓ | ✓ | ✗ | ✗ | ✗ |
| **v** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **t** | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 |
| **ref** | **9** | **6** | **23** | **32** | **24** | **19** | **28** | **15** | **48** | **21** | **49** | **48** | **49** | **26** | **21** | **18** | **38** | **0** | **38** | **40** | **16** | **24** | **9** | **3** | **5** | **6** | **1** | **27** | **30** | **37** |
| **f** | 9 | 6 | 23 | 32 | 24 | 19 | 28 | 15 | 48 | 21 | 49 | 48 | 49 | 26 | 21 | 18 | 38 | 0 | 38 | 40 | 16 | 24 | 9 | 3 | 5 | 6 | 1 | 27 | 30 | 37 |
| **f** | 13 | 9 | 6 | 23 | 32 | 24 | 19 | 28 | 15 | 48 | 21 | 49 | 48 | 49 | 26 | 21 | 18 | 38 | 0 | 38 | 40 | 16 | 24 | 9 | 3 | 5 | 6 | 1 | 27 | 30 |
| **f** | 36 | 13 | 9 | 6 | 23 | 32 | 24 | 19 | 28 | 15 | 48 | 21 | 21 | 48 | 49 | 26 | 21 | 18 | 18 | 0 | 38 | 40 | 16 | 24 | 9 | 3 | 5 | 6 | 1 | 27 |
| **f** | 24 | 36 | 13 | 9 | 6 | 23 | 32 | 24 | 19 | 28 | 15 | 15 | 15 | 21 | 48 | 49 | 26 | 21 | 21 | 18 | 0 | 38 | 40 | 16 | 24 | 9 | 3 | 5 | 6 | 1 |
| **f** | 21 | 24 | 36 | 13 | 9 | 6 | 23 | 32 | 24 | 19 | 28 | 28 | 28 | 15 | 15 | 48 | 49 | 26 | 26 | 21 | 18 | 0 | 38 | 40 | 16 | 24 | 9 | 3 | 5 | 6 |
| **f** | 45 | 21 | 24 | 36 | 13 | 9 | 6 | 23 | 32 | 24 | 19 | 19 | 19 | 28 | 28 | 15 | 48 | 49 | 49 | 26 | 21 | 18 | 0 | 38 | 40 | 16 | 24 | 9 | 3 | 5 |
| **f** | 29 | 45 | 21 | 24 | 36 | 13 | 9 | 6 | 23 | 32 | 24 | 24 | 24 | 19 | 19 | 28 | 15 | 48 | 48 | 49 | 26 | 21 | 18 | 0 | 38 | 40 | 16 | 24 | 9 | 3 |
| **f** | 35 | 29 | 45 | 21 | 21 | 36 | 13 | 9 | 6 | 23 | 32 | 32 | 32 | 24 | 24 | 19 | 28 | 15 | 15 | 48 | 49 | 26 | 21 | 18 | 0 | 38 | 40 | 16 | 24 | 9 |
| **f** | 19 | 35 | 29 | 45 | 45 | 21 | 36 | 13 | 9 | 6 | 23 | 23 | 23 | 32 | 32 | 24 | 19 | 28 | 28 | 15 | 48 | 49 | 26 | 21 | 18 | 0 | 38 | 40 | 16 | 24 |
| **f** | 34 | 19 | 35 | 29 | 29 | 45 | 21 | 36 | 13 | 9 | 6 | 6 | 6 | 23 | 23 | 32 | 24 | 19 | 19 | 28 | 15 | 48 | 49 | 26 | 21 | 18 | 0 | 38 | 40 | 16 |
| **f** | 14 | 34 | 19 | 35 | 35 | 29 | 45 | 21 | 36 | 13 | 9 | 9 | 9 | 6 | 6 | 23 | 32 | 24 | 24 | 19 | 28 | 15 | 48 | 49 | 26 | 21 | 18 | 0 | 38 | 40 |
| **f** | 49 | 14 | 34 | 19 | 19 | 35 | 29 | 45 | 21 | 36 | 13 | 13 | 13 | 9 | 9 | 6 | 23 | 32 | 32 | 24 | 19 | 28 | 15 | 48 | 49 | 26 | 21 | 18 | 0 | 38 |
| **f** | 10 | 49 | 14 | 34 | 34 | 34 | 35 | 29 | 45 | 45 | 36 | 36 | 36 | 13 | 13 | 9 | 6 | 23 | 23 | 32 | 24 | 19 | 28 | 15 | 48 | 49 | 26 | 21 | 18 | 0 |
| **f** | 17 | 10 | 49 | 14 | 14 | 14 | 34 | 35 | 29 | 29 | 45 | 45 | 45 | 36 | 36 | 13 | 9 | 6 | 6 | 23 | 32 | 32 | 19 | 28 | 15 | 48 | 49 | 26 | 21 | 18 |
| **f** | 25 | 17 | 10 | 49 | 49 | 49 | 14 | 34 | 35 | 35 | 29 | 29 | 29 | 45 | 45 | 36 | 13 | 9 | 9 | 6 | 23 | 23 | 32 | 19 | 28 | 15 | 48 | 49 | 26 | 21 |
| **f** | 28 | 25 | 17 | 10 | 10 | 10 | 49 | 14 | 34 | 34 | 35 | 35 | 35 | 29 | 29 | 45 | 36 | 13 | 13 | 9 | 6 | 6 | 23 | 32 | 19 | 28 | 15 | 48 | 49 | 26 |
| **f** | 32 | 28 | 25 | 17 | 17 | 17 | 10 | 49 | 14 | 14 | 34 | 34 | 34 | 35 | 35 | 29 | 45 | 36 | 36 | 13 | 9 | 9 | 6 | 23 | 32 | 19 | 28 | 15 | 48 | 49 |
| **f** | 40 | 32 | 28 | 25 | 25 | 25 | 17 | 10 | 49 | 49 | 14 | 14 | 14 | 34 | 34 | 35 | 29 | 45 | 45 | 36 | 13 | 13 | 13 | 6 | 23 | 32 | 19 | 28 | 15 | 48 |
| **f** | 41 | 40 | 32 | 28 | 28 | 28 | 25 | 17 | 10 | 10 | 10 | 10 | 10 | 14 | 14 | 34 | 35 | 29 | 29 | 45 | 36 | 36 | 36 | 13 | 6 | 23 | 32 | 19 | 28 | 15 |
| **f** | 44 | 41 | 40 | 40 | 40 | 40 | 40 | 25 | 17 | 17 | 17 | 17 | 17 | 10 | 10 | 14 | 34 | 35 | 35 | 29 | 45 | 45 | 45 | 36 | 13 | 13 | 23 | 32 | 19 | 28 |
| **f** | 46 | 44 | 41 | 41 | 41 | 41 | 41 | 40 | 25 | 25 | 25 | 25 | 25 | 17 | 17 | 10 | 14 | 34 | 34 | 35 | 29 | 29 | 29 | 45 | 36 | 36 | 13 | 23 | 32 | 19 |
| **f** | 15 | 46 | 44 | 44 | 44 | 44 | 44 | 41 | 40 | 40 | 40 | 40 | 40 | 25 | 25 | 17 | 10 | 14 | 14 | 34 | 35 | 35 | 35 | 29 | 45 | 45 | 36 | 13 | 23 | 32 |
| **f** | 23 | 15 | 46 | 46 | 46 | 46 | 46 | 44 | 41 | 41 | 41 | 41 | 41 | 40 | 40 | 25 | 17 | 10 | 10 | 14 | 34 | 34 | 34 | 35 | 29 | 29 | 45 | 36 | 13 | 23 |
| **f** |  | 23 | 15 | 15 | 15 | 15 | 15 | 46 | 44 | 44 | 44 | 44 | 44 | 41 | 41 | 40 | 25 | 17 | 17 | 10 | 14 | 14 | 14 | 34 | 35 | 35 | 29 | 45 | 36 | 13 |
| **f** |  |  |  |  |  |  |  |  | 46 | 46 | 46 | 46 | 46 | 44 | 44 | 41 | 40 | 25 | 25 | 17 | 10 | 10 | 10 | 14 | 34 | 34 | 35 | 29 | 45 | 36 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  | 46 | 46 | 44 | 41 | 40 | 40 | 25 | 17 | 17 | 17 | 10 | 14 | 14 | 34 | 35 | 29 | 45 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 46 | 44 | 41 | 41 | 41 | 25 | 25 | 25 | 17 | 10 | 10 | 14 | 34 | 35 | 29 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 46 | 44 | 44 | 44 | 41 | 41 | 41 | 25 | 17 | 17 | 10 | 14 | 34 | 35 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 46 | 46 | 46 | 44 | 44 | 44 | 41 | 25 | 25 | 17 | 10 | 14 | 34 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 46 | 46 | 46 | 44 | 41 | 41 | 25 | 17 | 10 | 14 |
| **hit** | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✗ | ✗ | ✗ | ✓ | ✓ | ✗ | ✓ | ✓ | ✗ | ✗ | ✓ | ✗ | ✗ | ✗ | ✗ |
| **v** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 46 | 44 |  | 41 | 25 | 17 | 10 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **t** | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 |
| **ref** | **40** | **39** | **46** | **14** | **21** | **22** | **35** | **2** | **39** | **36** | **23** | **39** | **36** | **24** | **17** | **9** | **42** | **6** | **9** | **30** | **46** | **27** | **4** | **7** | **30** | **10** | **13** | **31** | **39** | **43** |
| **f** | 40 | 39 | 46 | 14 | 21 | 22 | 35 | 2 | 39 | 36 | 23 | 39 | 36 | 24 | 17 | 9 | 42 | 6 | 9 | 30 | 46 | 27 | 4 | 7 | 30 | 10 | 13 | 31 | 39 | 43 |
| **f** | 37 | 40 | 39 | 46 | 14 | 21 | 22 | 35 | 2 | 39 | 36 | 23 | 39 | 36 | 24 | 17 | 9 | 42 | 6 | 9 | 30 | 46 | 27 | 4 | 7 | 30 | 10 | 13 | 31 | 39 |
| **f** | 30 | 37 | 40 | 39 | 46 | 14 | 21 | 22 | 35 | 2 | 39 | 36 | 23 | 39 | 36 | 24 | 17 | 9 | 42 | 6 | 9 | 30 | 46 | 27 | 4 | 7 | 30 | 10 | 13 | 31 |
| **f** | 27 | 30 | 37 | 40 | 39 | 46 | 14 | 21 | 22 | 35 | 2 | 2 | 2 | 23 | 39 | 36 | 24 | 17 | 17 | 42 | 6 | 9 | 30 | 46 | 27 | 4 | 7 | 30 | 10 | 13 |
| **f** | 1 | 27 | 30 | 37 | 40 | 39 | 46 | 14 | 21 | 22 | 35 | 35 | 35 | 2 | 23 | 39 | 36 | 24 | 24 | 17 | 42 | 6 | 9 | 30 | 46 | 27 | 4 | 7 | 30 | 10 |
| **f** | 6 | 1 | 27 | 30 | 37 | 40 | 39 | 46 | 14 | 21 | 22 | 22 | 22 | 35 | 2 | 23 | 39 | 36 | 36 | 24 | 17 | 42 | 6 | 9 | 9 | 46 | 27 | 4 | 7 | 30 |
| **f** | 5 | 6 | 1 | 27 | 30 | 37 | 40 | 39 | 46 | 14 | 21 | 21 | 21 | 22 | 35 | 2 | 23 | 39 | 39 | 36 | 24 | 17 | 42 | 6 | 6 | 9 | 46 | 27 | 4 | 7 |
| **f** | 3 | 5 | 6 | 1 | 27 | 30 | 37 | 40 | 40 | 46 | 14 | 14 | 14 | 21 | 22 | 35 | 2 | 23 | 23 | 39 | 36 | 24 | 17 | 42 | 42 | 6 | 9 | 46 | 27 | 4 |
| **f** | 9 | 3 | 5 | 6 | 1 | 27 | 30 | 37 | 37 | 40 | 46 | 46 | 46 | 14 | 21 | 22 | 35 | 2 | 2 | 23 | 39 | 36 | 24 | 17 | 17 | 42 | 6 | 9 | 46 | 27 |
| **f** | 24 | 9 | 3 | 5 | 6 | 1 | 27 | 30 | 30 | 37 | 40 | 40 | 40 | 46 | 14 | 21 | 22 | 35 | 35 | 2 | 23 | 39 | 36 | 24 | 24 | 17 | 42 | 6 | 9 | 46 |
| **f** | 16 | 24 | 9 | 3 | 5 | 6 | 1 | 27 | 27 | 30 | 37 | 37 | 37 | 40 | 46 | 14 | 21 | 22 | 22 | 35 | 2 | 23 | 39 | 36 | 36 | 24 | 17 | 42 | 6 | 9 |
| **f** | 38 | 16 | 24 | 9 | 3 | 5 | 6 | 1 | 1 | 27 | 30 | 30 | 30 | 37 | 40 | 46 | 14 | 21 | 21 | 22 | 35 | 2 | 23 | 39 | 39 | 36 | 24 | 17 | 42 | 6 |
| **f** | 0 | 38 | 16 | 24 | 9 | 3 | 5 | 6 | 6 | 1 | 27 | 27 | 27 | 30 | 37 | 40 | 46 | 14 | 14 | 21 | 22 | 35 | 2 | 23 | 23 | 39 | 36 | 24 | 17 | 42 |
| **f** | 18 | 0 | 38 | 16 | 24 | 9 | 3 | 5 | 5 | 6 | 1 | 1 | 1 | 27 | 30 | 37 | 40 | 46 | 46 | 14 | 21 | 22 | 35 | 2 | 2 | 23 | 39 | 36 | 24 | 17 |
| **f** | 21 | 18 | 0 | 38 | 16 | 24 | 9 | 3 | 3 | 5 | 6 | 6 | 6 | 1 | 27 | 30 | 37 | 40 | 40 | 46 | 14 | 21 | 22 | 35 | 35 | 2 | 23 | 39 | 36 | 24 |
| **f** | 26 | 21 | 18 | 0 | 38 | 16 | 24 | 9 | 9 | 3 | 5 | 5 | 5 | 6 | 1 | 27 | 30 | 37 | 37 | 40 | 40 | 14 | 21 | 22 | 22 | 35 | 2 | 23 | 23 | 36 |
| **f** | 49 | 26 | 21 | 18 | 0 | 38 | 16 | 24 | 24 | 9 | 3 | 3 | 3 | 5 | 6 | 1 | 27 | 30 | 30 | 37 | 37 | 40 | 14 | 21 | 21 | 22 | 35 | 2 | 2 | 23 |
| **f** | 48 | 49 | 26 | 21 | 18 | 0 | 38 | 16 | 16 | 24 | 9 | 9 | 9 | 3 | 5 | 6 | 1 | 27 | 27 | 27 | 27 | 37 | 40 | 14 | 14 | 21 | 22 | 35 | 35 | 2 |
| **f** | 15 | 48 | 49 | 26 | 26 | 18 | 0 | 38 | 38 | 16 | 24 | 24 | 24 | 9 | 3 | 5 | 6 | 1 | 1 | 1 | 1 | 1 | 37 | 40 | 40 | 14 | 21 | 22 | 22 | 35 |
| **f** | 28 | 15 | 48 | 49 | 49 | 26 | 18 | 0 | 0 | 38 | 16 | 16 | 16 | 16 | 9 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 1 | 37 | 37 | 40 | 14 | 21 | 21 | 22 |
| **f** | 19 | 28 | 15 | 48 | 48 | 49 | 26 | 18 | 18 | 0 | 38 | 38 | 38 | 38 | 16 | 16 | 3 | 3 | 3 | 3 | 3 | 3 | 5 | 1 | 1 | 37 | 40 | 14 | 14 | 21 |
| **f** | 32 | 19 | 28 | 15 | 15 | 48 | 49 | 26 | 26 | 18 | 0 | 0 | 0 | 0 | 38 | 38 | 16 | 16 | 16 | 16 | 16 | 16 | 3 | 5 | 5 | 1 | 37 | 40 | 40 | 14 |
| **f** | 23 | 32 | 19 | 28 | 28 | 15 | 48 | 49 | 49 | 26 | 18 | 18 | 18 | 18 | 0 | 0 | 38 | 38 | 38 | 38 | 38 | 38 | 16 | 3 | 3 | 5 | 1 | 37 | 37 | 40 |
| **f** | 13 | 23 | 32 | 19 | 19 | 28 | 15 | 48 | 48 | 49 | 26 | 26 | 26 | 26 | 18 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 38 | 16 | 16 | 3 | 5 | 1 | 1 | 37 |
| **f** | 36 | 13 | 23 | 32 | 32 | 19 | 28 | 15 | 15 | 48 | 49 | 49 | 49 | 49 | 26 | 26 | 18 | 18 | 18 | 18 | 18 | 18 | 0 | 38 | 38 | 16 | 3 | 5 | 5 | 1 |
| **f** | 45 | 36 | 13 | 23 | 23 | 32 | 19 | 28 | 28 | 15 | 48 | 48 | 48 | 48 | 49 | 49 | 26 | 26 | 26 | 26 | 26 | 26 | 18 | 0 | 0 | 38 | 16 | 3 | 3 | 5 |
| **f** | 29 | 45 | 36 | 13 | 13 | 23 | 32 | 19 | 19 | 28 | 15 | 15 | 15 | 15 | 48 | 48 | 49 | 49 | 49 | 49 | 49 | 49 | 26 | 18 | 18 | 0 | 38 | 16 | 16 | 3 |
| **f** | 35 | 29 | 45 | 36 | 36 | 13 | 23 | 32 | 32 | 19 | 28 | 28 | 28 | 28 | 15 | 15 | 48 | 48 | 48 | 48 | 48 | 48 | 49 | 26 | 26 | 18 | 0 | 38 | 38 | 16 |
| **f** | 34 | 35 | 29 | 45 | 45 | 36 | 13 | 23 | 23 | 32 | 19 | 19 | 19 | 19 | 28 | 28 | 15 | 15 | 15 | 15 | 15 | 15 | 48 | 49 | 49 | 26 | 18 | 0 | 0 | 38 |
| **f** | 14 | 34 | 35 | 29 | 29 | 45 | 36 | 13 | 13 | 23 | 32 | 32 | 32 | 32 | 19 | 19 | 28 | 28 | 28 | 28 | 28 | 28 | 15 | 48 | 48 | 49 | 26 | 18 | 18 | 0 |
| **hit** | ✓ | ✗ | ✗ | ✗ | ✓ | ✗ | ✗ | ✗ | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✓ | ✗ | ✗ | ✗ | ✓ | ✗ |
| **v** |  | 14 | 34 | 35 |  | 29 | 45 | 36 |  | 13 |  |  |  |  | 32 |  | 19 |  |  |  |  |  | 28 | 15 |  | 48 | 49 | 26 |  | 18 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **t** | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **ref** | **21** | **29** | **34** | **19** | **45** | **7** | **41** | **31** | **9** | **30** | **17** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** | 21 | 29 | 34 | 19 | 45 | 7 | 41 | 31 | 9 | 30 | 17 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 43 | 21 | 29 | 34 | 19 | 45 | 7 | 41 | 31 | 9 | 30 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 39 | 43 | 21 | 29 | 34 | 19 | 45 | 7 | 41 | 31 | 9 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 31 | 39 | 43 | 21 | 29 | 34 | 19 | 45 | 7 | 41 | 31 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 13 | 31 | 39 | 43 | 21 | 29 | 34 | 19 | 45 | 7 | 41 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 10 | 13 | 31 | 39 | 43 | 21 | 29 | 34 | 19 | 45 | 7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 30 | 10 | 13 | 31 | 39 | 43 | 21 | 29 | 34 | 19 | 45 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 7 | 30 | 10 | 13 | 31 | 39 | 43 | 21 | 29 | 34 | 19 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 4 | 7 | 30 | 10 | 13 | 31 | 39 | 43 | 21 | 29 | 34 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 27 | 4 | 7 | 30 | 10 | 13 | 31 | 39 | 43 | 21 | 29 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 46 | 27 | 4 | 7 | 30 | 10 | 13 | 13 | 39 | 43 | 21 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 9 | 46 | 27 | 4 | 7 | 30 | 10 | 10 | 13 | 39 | 43 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 6 | 9 | 46 | 27 | 4 | 4 | 30 | 30 | 10 | 13 | 39 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 42 | 6 | 9 | 46 | 27 | 27 | 4 | 4 | 30 | 10 | 13 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 17 | 42 | 6 | 9 | 46 | 46 | 27 | 27 | 4 | 4 | 10 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 24 | 17 | 42 | 6 | 9 | 9 | 46 | 46 | 27 | 27 | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 36 | 24 | 17 | 42 | 6 | 6 | 9 | 9 | 46 | 46 | 27 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 23 | 36 | 24 | 17 | 42 | 42 | 6 | 6 | 6 | 6 | 46 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 2 | 23 | 36 | 24 | 17 | 17 | 42 | 42 | 42 | 42 | 6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 35 | 2 | 23 | 36 | 24 | 24 | 17 | 17 | 17 | 17 | 42 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 22 | 35 | 2 | 23 | 36 | 36 | 24 | 24 | 24 | 24 | 24 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 14 | 22 | 35 | 2 | 23 | 23 | 36 | 36 | 36 | 36 | 36 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 40 | 14 | 22 | 35 | 2 | 2 | 23 | 23 | 23 | 23 | 23 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 37 | 40 | 14 | 22 | 35 | 35 | 2 | 2 | 2 | 2 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 1 | 37 | 40 | 14 | 22 | 22 | 35 | 35 | 35 | 35 | 35 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 5 | 1 | 37 | 40 | 14 | 14 | 22 | 22 | 22 | 22 | 22 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 3 | 5 | 1 | 37 | 40 | 40 | 14 | 14 | 14 | 14 | 14 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 16 | 3 | 5 | 1 | 37 | 37 | 40 | 40 | 40 | 40 | 40 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 38 | 16 | 3 | 5 | 1 | 1 | 37 | 37 | 37 | 37 | 37 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 0 | 38 | 16 | 3 | 5 | 5 | 1 | 1 | 1 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **hit** | ✓ | ✗ | ✗ | ✗ | ✗ | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **v** |  |  | 38 | 16 | 3 |  | 5 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

* Total references: 100
* Total distinct references: 44
* Hits: 44
* Faults: 56
* **Hit rate:** 44/100 = **44**%
* **Fault rate:** 56/100 = **56**%

# Summary - OPT algorithm

A theoretically optimal page replacement algorithm that has the lowest page-fault rate of all algorithms and never suffers from Belady's anomaly. The method replaces the page that will not be used for the longest period of time.

Solution visualization

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **t** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| **ref** |  | **10** | **23** | **15** | **46** | **44** | **41** | **29** | **40** | **32** | **49** | **28** | **25** | **21** | **17** | **10** | **29** | **19** | **49** | **14** | **34** | **19** | **35** | **29** | **45** | **45** | **21** | **24** | **36** | **13** |
| **f** |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 25 | 21 | 17 | 17 | 17 | 19 | 19 | 14 | 34 | 34 | 35 | 35 | 45 | 45 | 45 | 24 | 36 | 13 |
| **f** |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 25 | 21 | 21 | 21 | 17 | 17 | 19 | 14 | 14 | 34 | 34 | 35 | 35 | 35 | 45 | 24 | 36 |
| **f** |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 25 | 25 | 25 | 21 | 21 | 17 | 19 | 19 | 14 | 14 | 34 | 34 | 34 | 35 | 45 | 24 |
| **f** |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 28 | 28 | 28 | 25 | 25 | 21 | 17 | 17 | 19 | 19 | 14 | 14 | 14 | 34 | 35 | 45 |
| **f** |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 49 | 49 | 49 | 28 | 28 | 25 | 21 | 21 | 17 | 17 | 19 | 19 | 19 | 14 | 34 | 35 |
| **f** |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 32 | 32 | 32 | 49 | 49 | 28 | 25 | 25 | 21 | 21 | 17 | 17 | 17 | 19 | 14 | 34 |
| **f** |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 40 | 40 | 40 | 32 | 32 | 49 | 28 | 28 | 25 | 25 | 21 | 21 | 21 | 17 | 19 | 14 |
| **f** |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 29 | 29 | 29 | 40 | 40 | 32 | 49 | 49 | 28 | 28 | 25 | 25 | 25 | 21 | 17 | 19 |
| **f** |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 41 | 41 | 41 | 29 | 29 | 40 | 32 | 32 | 49 | 49 | 28 | 28 | 28 | 25 | 21 | 17 |
| **f** |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 44 | 44 | 44 | 41 | 41 | 29 | 40 | 40 | 32 | 32 | 49 | 49 | 49 | 28 | 25 | 21 |
| **f** |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 46 | 46 | 46 | 44 | 44 | 41 | 29 | 29 | 40 | 40 | 32 | 32 | 32 | 49 | 28 | 25 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 15 | 15 | 46 | 46 | 44 | 41 | 41 | 29 | 29 | 40 | 40 | 40 | 32 | 49 | 28 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 23 | 23 | 15 | 15 | 46 | 44 | 44 | 41 | 41 | 29 | 29 | 29 | 40 | 32 | 49 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 10 | 23 | 23 | 15 | 46 | 46 | 44 | 44 | 41 | 41 | 41 | 29 | 40 | 32 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 23 | 15 | 15 | 46 | 46 | 44 | 44 | 44 | 41 | 29 | 40 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 23 | 15 | 15 | 46 | 46 | 46 | 44 | 41 | 29 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 23 | 23 | 15 | 15 | 15 | 46 | 44 | 41 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 23 | 23 | 23 | 15 | 46 | 44 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 10 | 23 | 15 | 46 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **hit** |  | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✓ | ✓ | ✗ | ✓ | ✗ | ✗ | ✓ | ✗ | ✓ | ✗ | ✓ | ✓ | ✗ | ✗ | ✗ |
| **v** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **t** | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 |
| **ref** | **9** | **6** | **23** | **32** | **24** | **19** | **28** | **15** | **48** | **21** | **49** | **48** | **49** | **26** | **21** | **18** | **38** | **0** | **38** | **40** | **16** | **24** | **9** | **3** | **5** | **6** | **1** | **27** | **30** | **37** |
| **f** | 9 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 48 | 48 | 48 | 48 | 48 | 26 | 26 | 18 | 38 | 0 | 0 | 0 | 16 | 16 | 16 | 3 | 5 | 5 | 1 | 27 | 30 | 37 |
| **f** | 13 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 6 | 6 | 6 | 6 | 6 | 48 | 48 | 26 | 18 | 38 | 38 | 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 30 |
| **f** | 36 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 9 | 9 | 9 | 9 | 9 | 6 | 6 | 48 | 26 | 18 | 18 | 18 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 27 |
| **f** | 24 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 13 | 13 | 13 | 13 | 13 | 9 | 9 | 6 | 48 | 26 | 26 | 26 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| **f** | 45 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 36 | 36 | 36 | 36 | 36 | 13 | 13 | 9 | 6 | 48 | 48 | 48 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 |
| **f** | 35 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 24 | 24 | 24 | 24 | 24 | 36 | 36 | 13 | 9 | 6 | 6 | 6 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| **f** | 34 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 45 | 45 | 45 | 45 | 45 | 24 | 24 | 36 | 13 | 9 | 9 | 9 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| **f** | 14 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 35 | 35 | 35 | 35 | 35 | 45 | 45 | 24 | 36 | 13 | 13 | 13 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| **f** | 19 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 34 | 34 | 34 | 34 | 34 | 35 | 35 | 45 | 24 | 36 | 36 | 36 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 |
| **f** | 17 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 14 | 14 | 14 | 14 | 14 | 34 | 34 | 35 | 45 | 24 | 24 | 24 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| **f** | 21 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 19 | 19 | 19 | 19 | 19 | 14 | 14 | 34 | 35 | 45 | 45 | 45 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 |
| **f** | 25 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 17 | 17 | 17 | 17 | 17 | 19 | 19 | 14 | 34 | 35 | 35 | 35 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| **f** | 28 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 21 | 21 | 21 | 21 | 21 | 17 | 17 | 19 | 14 | 34 | 34 | 34 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 |
| **f** | 49 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 25 | 25 | 25 | 25 | 25 | 21 | 21 | 17 | 19 | 14 | 14 | 14 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 |
| **f** | 32 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 28 | 28 | 28 | 28 | 28 | 25 | 25 | 21 | 17 | 19 | 19 | 19 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 |
| **f** | 40 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 49 | 49 | 49 | 49 | 49 | 28 | 28 | 25 | 21 | 17 | 17 | 17 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| **f** | 29 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 32 | 32 | 32 | 32 | 32 | 49 | 49 | 28 | 25 | 21 | 21 | 21 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| **f** | 41 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 40 | 40 | 40 | 40 | 40 | 32 | 32 | 49 | 28 | 25 | 25 | 25 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 |
| **f** | 44 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 29 | 29 | 29 | 29 | 29 | 40 | 40 | 32 | 49 | 28 | 28 | 28 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| **f** | 46 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 41 | 41 | 41 | 41 | 41 | 29 | 29 | 40 | 32 | 49 | 49 | 49 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 |
| **f** | 15 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 44 | 44 | 44 | 44 | 44 | 41 | 41 | 29 | 40 | 32 | 32 | 32 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 |
| **f** | 23 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 46 | 46 | 46 | 46 | 46 | 44 | 44 | 41 | 29 | 40 | 40 | 40 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| **f** | 10 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 15 | 15 | 15 | 15 | 15 | 46 | 46 | 44 | 41 | 29 | 29 | 29 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| **f** |  | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 23 | 23 | 23 | 23 | 23 | 15 | 15 | 46 | 44 | 41 | 41 | 41 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 |
| **f** |  |  |  |  |  |  |  |  | 10 | 10 | 10 | 10 | 10 | 23 | 23 | 15 | 46 | 44 | 44 | 44 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 23 | 15 | 46 | 46 | 46 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 15 | 15 | 15 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 23 | 23 | 23 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 10 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 |
| **f** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| **hit** | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✗ | ✗ | ✗ | ✓ | ✓ | ✗ | ✓ | ✓ | ✗ | ✗ | ✓ | ✗ | ✗ | ✗ | ✗ |
| **v** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 16 | 3 |  | 5 | 1 |  | 38 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **t** | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 |
| **ref** | **40** | **39** | **46** | **14** | **21** | **22** | **35** | **2** | **39** | **36** | **23** | **39** | **36** | **24** | **17** | **9** | **42** | **6** | **9** | **30** | **46** | **27** | **4** | **7** | **30** | **10** | **13** | **31** | **39** | **43** |
| **f** | 37 | 39 | 39 | 39 | 39 | 22 | 22 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 42 | 42 | 42 | 42 | 42 | 42 | 4 | 7 | 7 | 7 | 7 | 31 | 31 | 43 |
| **f** | 30 | 30 | 30 | 30 | 30 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 7 | 7 | 31 |
| **f** | 27 | 27 | 27 | 27 | 27 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 39 | 39 | 7 |
| **f** | 18 | 18 | 18 | 18 | 18 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 30 | 30 | 30 |
| **f** | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 |
| **f** | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| **f** | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| **f** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| **f** | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 |
| **f** | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| **f** | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 |
| **f** | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| **f** | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 |
| **f** | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 |
| **f** | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 |
| **f** | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| **f** | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| **f** | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 |
| **f** | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| **f** | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 |
| **f** | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 |
| **f** | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| **f** | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| **f** | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 |
| **f** | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 |
| **f** | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 |
| **f** | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 |
| **f** | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| **f** | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 |
| **f** | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| **hit** | ✓ | ✗ | ✓ | ✓ | ✓ | ✗ | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✓ | ✓ | ✓ | ✗ | ✓ | ✗ |
| **v** |  | 37 |  |  |  | 18 |  | 22 |  |  |  |  |  |  |  |  | 2 |  |  |  |  |  | 42 | 4 |  |  |  | 27 |  | 39 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **t** | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **ref** | **21** | **29** | **34** | **19** | **45** | **7** | **41** | **31** | **9** | **30** | **17** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **f** | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 31 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 29 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **f** | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **hit** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **v** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

* Total references: 100
* Total distinct references: 44
* Hits: 56
* Faults: 44
* **Hit rate:** 56/100 = **56**%
* **Fault rate:** 44/100 = **44**%

Page sources:

<http://solver.assistedcoding.eu/page_replacement>

# Results and Instruction on how run in linux

After opening the Linux server and logging in:

1. Import the program file. I use Cryptonaut which allows me to copy and past my files directly into the directory.
2. Move to the directory using cd project2
3. Within the directory where the program file is stored enter the following code:  
   g++ -std=c++11 main.cpp -o project2
4. Type:

./project2

Program should run automatically like the screenshot below.

