**Operating Systems Design** : Tutorial 03 - Memory management

*Question 1 : Describe how internal fragmentation and external fragmentation can happen in fixed contiguous memory allocation systems.*

> In fixed contiguous memory allocation systems, arbitrary partition sizes lead to undesired results, too large a partition size results in memory waste or “internal fragmentation” (memory in a partition not used by a process is not available to other processes). There is no external fragmentation for fixed partitions.

*Question 2 : A program requests pages in the following order:*

***d c b a d c e d c b a e****Construct a page trace analysis indicating page faults with an asterisk (\*) using FIFO, where :  
  
(i). Memory is divided into 3 page frames*

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Page requests* | ***D*** | ***C*** | ***B*** | ***A*** | ***D*** | ***C*** | ***E*** | ***D*** | ***C*** | ***B*** | ***A*** | ***E*** |
| *Page frame 1* | *D* | *D* | *D* | *A* | *A* | *A* | *E* | *E* | *E* | *E* | *E* | *E* |
| *Page frame 2* |  | *C* | *C* | *C* | *D* | *D* | *D* | *D* | *D* | *B* | *B* | *B* |
| *Page frame 3* |  |  | *B* | *B* | *B* | *C* | *C* | *C* | *C* | *C* | *A* | *A* |
| *Page fault* | *\** | *\** | *\** | *\** | *\** | *\** | *\** |  |  | *\** | *\** |  |

*(ii). Memory is divided into 4 page frames*

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Page requests* | ***D*** | ***C*** | ***B*** | ***A*** | ***D*** | ***C*** | ***E*** | ***D*** | ***C*** | ***B*** | ***A*** | ***E*** |
| *Page frame 1* | *D* | *D* | *D* | *D* | *D* | *D* | *E* | *E* | *E* | *E* | *A* | *A* |
| *Page frame 2* |  | *C* | *C* | *C* | *C* | *C* | *C* | *D* | *D* | *D* | *D* | *E* |
| *Page frame 3* |  |  | *B* | *B* | *B* | *B* | *B* | *B* | *C* | *C* | *C* | *C* |
| *Page frame 4* |  |  |  | *A* | *A* | *A* | *A* | *A* | *A* | *B* | *B* | *B* |
| *Page fault* | *\** | *\** | *\** | *\** |  |  | *\** | *\** | *\** | *\** | *\** | *\** |

*Question 3 : Modern computers use virtual memory.*

*(i). Briefly explain what is meant by virtual memory.*

> The virtual memory is a memory management capability (or a storage allocation scheme) in which secondary memory can be addressed as though it were part of the main memory. Virtual memory allows programs to be executed even though they are not stored entirely in memory.

*(ii). Give two advantages of virtual memory.*

> The virtual memory helps to eliminate the need for entire program to reside in memory during execution and also to remove the restriction of storing programs contiguously.

*Question 4 : Explain the following terms :*

*(i). Thrashing :* It is an excessive amount of page swapping between main memory and secondary storage (caused when a page is removed from memory but is called back shortly thereafter).

*(ii). Least recently used page :* It is a page replacement policy. It removes page that has been least recently accessed (not to be confused with FIFO for example).

*(iii). The working set of pages in demand paging :* Set of pages residing in memory that can be accessed directly without incurring a page fault. It improves performance of demand page schemes.

*(iv). Memory compaction :* Reclaiming fragmented sections of the memory space. With memory compaction, every program in memory must be relocated so they are contiguous.

*(v). Page modified bit :* Page that needs to be rewritten to secondary storage when it’s swapped out. A modified bit indicates if page contents have been altered.

*Question 5 : What is “Belady’s anomaly” in page allocation algorithms? Why does it occur?*

> Belady’s anomaly is the phenomenon where increasing page frames using FIFO (First One, First Out) strategy results in increase in number of page faults, instead of decrease, for a given memory pattern. If at any moment, the set of pages in the 3-frame memory is not a subset of the set in the 4-frame memory then this means that the 4-frame memory will producing a page fault that does not occur in the 3-frame memory.