(1) What is “virtual memory” and what are the primary advantages in virtual memory (at least three)?

- Virtual memory is a mechanism that provides a larger memory address space to processors using the capacity of hard-drives and the (physical) RAM memory.

OR

“It is a mechanism that expands memory space by mapping some of the virtual memory address space to hard drive” (from CS-286)

**Advantages:**
- Processes larger than the physical memory capacity can be executed.
- Processes will start up more quickly (since processes can start running as long as their first portion is loaded to the physical memory). **Note:** Processes will NOT run faster (actually slower because of page faults), but they start quicker.
- No external memory fragmentation (external memory fragmentation will never happen).

(2) Which of FIFO or LRU memory page replacement algorithm does result in fewer page faults and why?

**Note:** the correct choice (FIFO or LRU) will not earn much credit if a correct reasoning is not provided.

**LRU** (Least Recently Used) page replacing algorithm usually results in fewer page faults than FIFO page-replacing algorithm because LRU takes advantage of “locality in memory reference” (the memory pages that are recently used will be used again in future. Thus, keeping them in the physical memory will result in fewer page faults).

**Note:** “fewer page faults because LRU replaces the most least recently used memory pages (or anything similar)” will not earn the full credit (it just spells out “LRU”).
(3) What is “(memory) working set”? How should it be utilized?

- Working set (of a process) means a collection of the segments of the memory space a process currently (or “at a given time”) needs to execute itself.

OR

- Working set (of a process) is the size of the memory a process needs for executing itself w/out causing serious page faults.

- The memory manager in an operating system should use the working set of each process to figure out how much memory space each memory should be allocated (as long as each process is allocated the memory size that contains its working set, that’s enough).

(4) What is “page faults”? Why are page-faults a serious issue?

Page fault is a situation the memory page requested by a processor is not currently mapped to a physical memory page.

Page faults are a serious issue, because a hard drive will be accessed to bring the missing memory page from the hard drive to a memory page in the physical memory, while accessing a hard drive is usually more than 1,000 times slower than a memory access in the physical memory.

(5) What is “Belady’s Anomaly”? What property (in page replacement algorithm) guarantees to avoid “Belady’s anomaly”?

Belady’s Anomaly means situations that a larger number of page faults happen after the (physical) memory space is increased (i.e., after more physical memory pages are available (while the page size remains the same)).

The “stack algorithm” property guarantees to avoid Belady’s Anomaly.