(1) Describe how processes differ from programs by mentioning at least three differences between them.

① Programs exist as “files” in storage devices (e.g., hard drives and USB drives), while processes exist in the memory.

② Programs are static, meaning that no matter how long we wait, nothing in a program will change (w/ some exceptions, such as infections by computer viruses), while processes are dynamic, meaning that their statuses, such as the amount of the assigned memory space and the processor time being used by each process constantly change.

③ Programs mainly consist of “program codes”, which are binary machine codes, while processes consist of additional dynamic data fields (in addition to “program codes”), such as PCB (including “a copy of processor registers”), heap, stack, and etc.

Note 1: There are some other acceptable “differences”.

Note 2: “Processes are programs in execution” does not describe a difference (but it is rather a definition of “process”).

Note 3: “dynamic data fields, such as heap and stack” and “PCB” mean the same concept (they are not counted as “two different differences”).
(2) Mention at least five different information contained in a PCB (you do not have to describe them).

Any five from the followings (there are many more):

① User ID  ② Process ID  ③ Execution Priority
④ the memory address location (address) a process occupies (or assigned)
⑤ Processor Time (how long a processor is used)  ⑥ Program Name
⑦ The Last Time this process used a processor
⑧ The short-term process scheduler state (ready, blocked, or running)

(3) What is the primary motivation(s) to use VM’s?

The primary motivation in using a VM (at least as described in the classroom) is:

For using multiple (different or same) operating systems: ① without rebooting a computer or
② as they are multitasked (or anything like, “a VM multitasks multiple operating systems”).

**Note 1:** for full credit, either ① or ② should be mentioned.

**Note 2:** “run multiple operating systems at a time” is not accurate (or at least not descriptive enough).

**Note 3:** “for using application programs for different operating systems at a computer” does not correctly explain “VM” (since another concept, “multi-boot computers”, just does it).

(4) What are the two major reasons the long-term scheduling rejects starting a new process?

(a) When a computer does not have enough memory to start a new process
(b) When a computer does not have a processor powerful enough to start a new process

**Note 1:** “to prevent thrashing” means only (b) (but not (a)).

**Note 2:** “when a computer does not have enough resource” is not specific enough.

(5) In the following sentence: “The long-term scheduler is the main component that controls __________ in multitasking operating systems”, fill out the blank by a word that best fits to the blank.

Any of the following three: “the degree of multitasking”, “degree”, and “thrashing”.

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