1. The memory technique called overlays is possible because of what property of some functions and procedures in a program?
   a. They are recursive functions. Thus the data region for one invocation of such a function can overlay the data region associated with an earlier invocation of the same function.
   b. They are used independently of other functions and procedures with the same property. As a result, two such functions need not be in physical memory at the same time.
   c. They are public functions and procedures. This means that they may be used by other programs, even if they are only present in memory at one location (that is, not part of the address space of each process using them).

2. If the overlay memory technique can be successfully used for a program, what is the most likely positive effect?
   a. The program will be able to execute using a smaller amount of memory than if overlaying was not used.
   b. The program will be more secure, because the physical memory locations it occupies will be protected from access by other programs in memory at the same time.
   c. The program will be able to execute faster than if overlaying was not used.

3. When using overlays, the overlay structure – that is, the information describing which regions of a program will occupy the same memory locations – is determined by
   a. the user.
   b. the virtual memory system.
   c. none of the other answer choices is correct.

4. In paged memory systems, the memory required by a program is broken into several pieces. The size of each piece is
   a. equal to the size of the largest logical component of the program.
   b. the same as every other piece.
   c. none of the other answer choices is correct.

5. In segmented memory systems, the memory required by a program is broken into several pieces. The size of each piece is
   a. equal to the size of the largest logical component of the program.
   b. the same as every other piece.
   c. based on the size of the logical components of the program (e.g. functions, subroutines, arrays).

6. Suppose we wish to use paging with a program that requires 22,000 bytes. Suppose the size of a page is 5,000 bytes. How many bytes will be unused in this case?
   a. 2,000 bytes
   b. 3,000 bytes
   c. It is impossible to tell from the information provided.

7. Suppose we wish to use paging with a program that requires 22,000 bytes. Suppose the size of a page is 5,000 bytes. Some storage will be unused in this case. This is an example of
   a. external fragmentation.
   b. poor planning.
   c. internal fragmentation.
8. Which of the following is a major task of the memory management unit (MMU) in modern processors?  
   a. translate virtual addresses to the corresponding physical addresses  
   b. read as much as possible from physical memory into a processor cache each time an access is made  
   c. write all modified data back to physical memory as quickly as possible

9. Which hardware component of a modern computer system generates virtual addresses?  
   a. the MMU  
   b. the CPU  
   c. the DMA controller

10. The size of an address space on a system is determined by  
    a. the size of the TLB (translation lookaside buffer).  
    b. the number of bits in an address.  
    c. the size of the level-2 processor cache memory.

11. What is the relation between the size of the virtual address space on a computer and the size of the physical address space?  
    a. The virtual address space size is always at least as large as the physical address space.  
    b. The sum of the sizes of these address spaces must be equal to 2 to the power N, where N is the number of bits in a virtual address.  
    c. There is not necessarily any relation between the sizes of these address spaces, other than that each is usually a power of two.

12. The term page frame refers to  
    a. one of the fixed-sized regions into which a program is divided so it can be used on a system supporting paging.  
    b. one of the fixed-sized regions into which the physical memory of a computer system supporting paging is divided.  
    c. None of the other answer choices is correct.

13. The term page refers to  
    a. one of the fixed-sized regions into which the physical memory of a computer system supporting paging is divided.  
    b. one of the fixed-sized regions into which a program is divided so it can be used on a system supporting paging.  
    c. an area in the physical memory of a computer system used to store, or frame information being moved between virtual and physical memory.

14. How much external fragmentation occurs when a system uses paged memory management?  
    a. There is approximately one-half page of external fragment for each program.  
    b. No external fragment occurs in this case.  
    c. There is approximately one-half page of external fragment for each program.

15. Suppose a system uses paged memory management, and pages of programs are not brought into memory until they are actually referenced. This technique is commonly called  
    a. demand paging.  
    b. on-request paging.  
    c. in-response paging.

16. Suppose a system uses paged memory management, and some pages of programs are brought into memory before they are actually needed. This technique is commonly called  
    a. prepaging.  
    b. demand paging.  
    c. just-in-time paging.
17. A virtual address in a particular paged computer system is divided into two pieces, a page number and an offset. The system uses 4096 byte pages. How many bits are in the offset portion of a virtual address for this system?
   a. It is impossible to tell from the information provided.
   b. 12 bits
   c. 8 bits

18. When the MMU (memory management unit) translates a virtual address to a physical address on a paged computer system, which part of the virtual address is not modified?
   a. the page number
   b. the offset
   c. None of the other answer choices is correct.

19. Assume a system using paged memory management divides each virtual address into a page number and an offset. To what does the MMU translate a page number, assuming the translation is possible?
   a. a page frame number
   b. a virtual address
   c. a different offset

20. Translation of page numbers to page frame numbers is done by the MMU (memory management unit). What data structure does the MMU use to accomplish this translation?
   a. the page table
   b. the page frame
   c. the local descriptor table

21. Each entry in the data structure that can be successfully used by the memory management unit (MMU) in a paged virtual memory system contains
   a. an offset.
   b. a page table number.
   c. a page frame number.

22. The data structure used by the MMU (memory management unit) in a system using paged memory management is essentially
   a. an array.
   b. a balanced binary tree.
   c. a hash table.

23. Which component of a virtual address is used by the MMU (memory management unit) to select an entry from the data structure used by the MMU?
   a. the page number
   b. the page frame number
   c. the number of bits in the virtual address

24. Because of the manner in which the MMU (memory management unit) selects entries from a page table, the data structure that represents the page table
   a. must be logically contiguous.
   b. is capable of being modified by the process itself.
   c. All of the above answer choices are correct.

25. Where, on most systems, is the entire page table stored?
   a. on disk
   b. in primary memory
   c. None of the above answer choices is correct.
26. Assume that page table entries are stored **only** in primary memory. How many references to primary memory would then be required to access an instruction or an instruction’s operand?

   a. four  
   b. It is impossible to tell from the information provided.  
   c. two

27. Suppose we do not require that each page of a program be present in primary memory at all times. In order to know which pages are present, and which ones aren’t, systems use a special bit called the presence bit. This bit is located

   a. in each page table entry.  
   b. in a metadata field associated with the file that contains the executable code for the program.  
   c. None of the other answer choices is correct.

28. The presence bit was called the *translation not valid* bit on the VAX-11 computer system. This name was appropriate because

   a. the program attempting to access the page was not permitted to access it, even if the page was present in physical memory.  
   b. the page frame number field in the page table entry was not correct if the page was not present in primary memory.  
   c. None of the above answer choices are correct.

29. What event occurs when a process attempts to access a page of virtual memory which has a page table entry indicating that page is not present in physical memory?

   a. a PDP fault  
   b. a page fault  
   c. an AGP fault

30. When a context switch occurs (when the processor switches from executing instructions for one process to instructions for another), how is the page table used by the MMU (memory management unit) affected by a context switch?

   a. Each page table entry is saved, and the contents of the page table entries are replaced by values appropriate for the process to which the processor is being switched.  
   b. A different page table, the one for the process to which the processor is being switched, must be used.  
   c. None of the other answer choices is correct.

31. Which of the following techniques is commonly used to eliminate the need for a region of contiguous memory larger than a page to be used for a page table?

   a. a larger physical address space  
   b. a larger virtual address space  
   c. a multi-level page table, like that used in the Intel x86 architecture

32. Many systems include bits in addition to the page frame number field in their page table entries. Which of the following is **not** such a bit?

   a. the *referenced* bit  
   b. the *presence* bit  
   c. the *recursive* bit

33. What is the **principle of locality**?

   a. A program that uses a small, localized region of virtual memory will execute more efficiently than a program that uses several different regions of virtual memory.  
   b. The set of page table entries used to map the virtual addresses used by a program changes membership slowly.  
   c. None of the other answer choices is correct.
34. If the principle of locality holds (as it does for virtually all well-behaved programs), how is the set of actively referenced page table entries (for a single program) affected?
   a. The set of page table entries continues to grow smaller.
   b. The set of page table entries changes membership slowly.
   c. The set of page table entries changes membership rapidly.

35. A relatively small set of the page table entries for a program that are accessed frequently are normally stored in a special type of memory. This type of memory is called
   a. associative memory.
   b. translator memory.
   c. shift-register memory.

36. Translation Lookaside Buffer (TLB) is the name often given to the memory in which frequently-used page table entries are stored. Entries in the TLB are not ordered in the same way as entries in the page table. Instead, these entries are
   a. stored by decreasing virtual address so a binary search can be used in mapping a virtual address.
   b. all searched in parallel for the proper entry to use in mapping a virtual address.
   c. None of the other answer choices is correct.

37. Since the memory used for a TLB is much more expensive than normal physical memory, TLBs are usually much smaller than physical memories. What precaution must be taken with the TLB entries when a context switch occurs?
   a. The entries that are not appropriate for the process to which the processor is being switched must not be modified.
   b. The entries that are not appropriate for the process to which the processor is being switched must be replaced, or at least invalidated.
   c. None of the other answer choices is correct.

38. The concept of a Content Addressable Memory was invented by
   a. Edgser Dijkstra.
   b. Steve Bourne.
   c. Maurice Wilkes.

39. The key used in a lookup in the associative memory used for a Translation Lookaside Buffer is
   a. a presence bit.
   b. a virtual page number.
   c. an offset in a virtual or physical page.

40. One alternative to the traditional MMU organization is to use only a cache of page table entries. If the desired page table entry is not in the cache of such entries,
   a. a page fault is generated and system software must make the page present and update the cache.
   b. the hardware automatically makes the required page present and updates the cache.
   c. None of the other answer choices is correct.

41. An inverted page table is indexed by page frame number, and not by virtual page number. Accessed only when the cache lookup for a virtual page number fails, it is appropriate for use
   a. when a system has very slow physical memory.
   b. when a system has a very large virtual address space.
   c. when a system has very fast physical memory.
42. When a page fault occurs because a needed page of a program is not present in physical memory, that page must be made present, usually by copying it from secondary storage (e.g. disk) into an available empty page frame. The system obtains an empty page frame
   a. by selecting the page frame most recently accessed by a program, and preserving its contents if they were modified.
   b. from a pool of such empty page frames, or by evicting a page from a filled page frame to make an empty page frame.
   c. None of the other answer choices is correct.

43. Which of the following pages is a likely candidate for removal from primary memory in order to make a page frame available for use?
   a. the page that contained the instruction that was just executed.
   b. a page that will never be accessed again by the process that previously needed it.
   c. a page that has been modified, and will be referenced later by its process.

44. The algorithm used to identify page frames that are candidates for becoming empty page frames is called
   a. the page frame generator algorithm.
   b. the page frame liberator.
   c. a page replacement algorithm.

45. Once a page has been selected for use as an empty page frame
   a. its contents must be preserved (e.g. on disk) if it has been modified.
   b. its contents are set to random values.
   c. it is placed at the head of a queue of empty page frames so it will be used as soon as possible.

46. The OPT, or optimal page replacement algorithm, is guaranteed to yield the best performance of any such algorithms. Why, therefore, is this algorithm not used in real operating systems?
   a. It requires maintaining an extensive history of the memory accesses that were previously made by all processes.
   b. It is a complex algorithm and is rarely implemented properly.
   c. It requires knowledge of the future.

47. If the OPT page replacement algorithm is not used in real operating systems, then of what value is it?
   a. Since OPT is optimal, a simulator can be used to determine the order in which pages should be replaced (as directed by OPT). Then the simulation results can be used in a real system.
   b. It indicates the best possible performance of any page replacement algorithm, and can be used as a yardstick against which the performance of other page replacement algorithms can be measured.
   c. None of the other answer choices is correct.

48. The modified bit in a page table entry is also frequently called
   a. the changed bit.
   b. the redacted bit.
   c. the dirty bit.

49. The Not Recently Used page replacement algorithm classifies each present page as being in one of four categories based on the value of the expression _______, where R is the value of the referenced bit for the page and M is the value of the modified bit for the page.
   a. R * 2 + M
   b. R * 2 - M
   c. R * 4 + M
50. The Not Used Recently page replacement algorithm classifies each present page as being in one of four numbered categories. When it selects one or more pages for replacement, they are selected from which of the numbered categories (that is not empty)?
   a. any category except the highest and lowest numbered categories
   b. the lowest numbered category
   c. the lowest numbered category that is an odd number

51. The FIFO page replacement algorithm attempts to replace those pages that have been in memory the longest, and are therefore the least likely to be needed in the future. Unfortunately, these pages may also have been in memory a long time because they are needed frequently. What modification of FIFO is used to adjust for this problem?
   a. the safe at home algorithm
   b. the second chance algorithm
   c. the second time around algorithm

52. How is a page’s referenced (R) bit used by the modification of the FIFO algorithm that attempts to allow frequently referenced pages to remain in memory longer?
   a. Each time a page reaches the head of the FIFO queue, the R bit is examined. If it is 0, the page is replaced. Otherwise, the R bit is set to 0 and the page is placed at the end of the list.
   b. The R bit is not used in this algorithm.
   c. None of the other answer choices is correct.

53. What is the clock algorithm?
   a. It is a page replacement algorithm that measures the time between references for a page in order to predict when the next reference will occur.
   b. It is a variant of the FIFO algorithm that selects a page for replacement only if it has been on the FIFO queue at least two seconds.
   c. It is a variant of the FIFO algorithm that uses a circular queue.

54. What is the name of the page replacement algorithm that selects pages that have not been used for the longest time of any pages in memory?
   a. the second life algorithm
   b. the NUR algorithm
   c. None of the other answer choices is correct.

55. The FIFO page replacement algorithm can exhibit an interesting behavior. We normally expect that when a program is allowed to use a larger number of page frames that the number of page faults will go down, or at least not increase. This is not always the case with the FIFO algorithm. This behavior is called _____.
   a. the page fault reversal syndrome.
   b. Belady’s anomaly.
   c. a transitory artifact.

56. Page replacement algorithms that can be provably shown to never generate more page faults when the number of page frames they are allowed to use increases are called ___________ algorithms.
   a. stack
   b. queue
   c. tree

57. The set of pages being actively used by a process is called its
   a. tool set.
   b. working group.
   c. working set.
58. Assume a program must fill each byte in a large two-dimensional array with some value. Which of the following approaches to that task will probably result in the largest working set size? Assume arrays are stored in row-major order (that is, all the elements of the first row of the array are stored together in memory just before the elements of the second row, and so forth).
   a. Pick random row and column numbers to identify the element to be filled, and continue until the entire array has been filled.
   b. Fill each of the array elements in the first column, then the second column, and so forth.
   c. Fill each of the array elements in the first row, in order, then the second row, and so forth.

59. What is the working set principle?
   a. A program will run most efficiently if all of the pages in its working set are arranged in row-major order in physical memory.
   b. A program must not be run unless its entire working set can be made resident in primary memory.
   c. None of the other answer choices is correct.

60. When a system is said to be thrashing, it is spending most of its time
   a. modifying or invalidating entries in page tables or the translation lookaside buffer.
   b. waiting for pages to be moved between primary and secondary memory.
   c. None of the other answer choices is correct.

61. To what do the terms global page replacement and local page replacement refer?
   a. whether all of the pages that are in a contiguous region around the last referenced page of the current process are considered as candidates for replacement, or all pages in the process.
   b. whether pages selected for replacement are chosen from all processes, or just from the pages belonging to the process needing additional pages.
   c. None of the other answer choices is correct.

62. We may determine that a program is in need of additional page frames when
   a. the rate at which it generates page faults is relatively high.
   b. it spends very little time in the blocked state.
   c. it uses a large amount of its virtual address space.

63. Which of the following is an advantage of a large page size?
   a. There will be more internal fragmentation.
   b. Page tables will be smaller.
   c. There will be more external fragmentation.

64. In a segmented virtual memory system, virtual memory addresses have two components. One of these components is ______.
   a. the size of the segment.
   b. a unique integer assigned to the segment whose address is being specified.
   c. None of the other answer choices is correct.

65. What type of fragmentation, if any, is exhibited by pure segmented virtual memory systems?
   a. internal fragmentation
   b. recursive fragmentation
   c. external fragmentation

66. One task that must be performed during virtual to physical address translation in a segmented system that is not required in a paged system is
   a. verifying that the offset in the segment is an even number.
   b. updating the referenced bit if the hardware uses it.
   c. verifying that the offset in the segment is not larger than the segment size.