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School of Informatics

WRITTEN EXAMINATION

Course Operating systems G1F, 6hp

Course Operating systems G1F, 7.5hp

Sub-course

Course code IT390G IT391G

Credits for written examination 6hp

Date 2023-10-24 Examination time 14:15-19:30

Examination responsible András Márki

Teachers concerned Simon Butler

Aid at the exam/appendices

Other

Instructions

- ☐ Take a new sheet of paper for each teacher.
- ☒ Take a new sheet of paper when starting a new question.
- ☒ Write only on one side of the paper.
- ☒ Write your name and personal ID No. on all pages you hand in.
- ☒ Use page numbering.
- ☒ Don´t use a red pen.
- ☒ Mark answered questions with a cross on the cover sheet.

Grade points

ECTS A: >=80% of points on the whole exam AND >= 25% on all of parts 1-2
ECTS B >=72.5% of points on the whole exam AND >= 25% on all of parts 1-2
ECTS C >=65% of points on the whole exam AND >= 25% on all of parts 1-2
ECTS D >= 57.5% of points on the whole exam AND >= 25% on all of parts 1-2
ECTS E >= 50% of points on the whole exam AND >= 25% on all of parts 1-2
ECTS F <50% of points on the whole exam OR <25% on any of parts 1-2 on their own

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Examination results should be made public within 18 working days

Good luck!

Total number of pages

Before you start: multiple-answer questions can have multiple correct answers. To get full marks, you should have selected all correct answers, and you should not have selected any wrong answer; **each correctly completed / not completed alternative is rewarded with 0,2 marks**. Enter the answer to the first part of the exam directly into the exam paper. Answers given otherwise do not count. Select an option by drawing a cross in the box. If you change your mind, fill in the whole box.

Properly completed responses: 

Amended response: 

For the parts where we expect a computation, please make sure you answered all questions and do have your computations present. Computations are preferably answered on the writing sheets. For the figures, please make sure that all necessary parts are present.

As you are answering on the sheets, you must write your name and (Swedish) person number even on the exam sheets.

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Part 1 (MARD):

- Describe and compare terms, techniques, and algorithms in process and thread handling, for example scheduling, communication, synchronization, and deadlock handling,

1 Process concepts (10 Points)

1.1 What characterizes an IO-bound process? (1 Point)

☐	Uses the CPU mostly.
☐	Uses the I/O mostly via interrupts run on the kernel.
☐	Usually requires high memory bandwidth.
☐	Is usually not dependent on the system disk.
☐	It is bookkeeping related, as IO is an abbreviation for Important Opinion.

1.2 Which of the following registers are necessary for communicating between the CPU and the memory? (1 Point)

☐	Memory buffer register (MBR)
☐	Load target register (LTR)
☐	Memory address register (MAR)
☐	Random access register (RAR)
☐	Instruction register (IR)

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1.3 Compare the **size** and the **speed** of the following devices in the storage-device hierarchy: cache, solid-state drive, register, main memory. You can draw a figure if needed. (2p)

1.4 Give an example of how inter-process cooperation is beneficial for (1) Information sharing (2) Computation speedup (3) Modularity (4) Convenience (2p).

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1.5 Draw a diagram illustrating a context switch from processes P1 and P2 on the CPU, marking the important parts accordingly. (4 Points)

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2 Threads (Total: 10 Points)

2.1 What are the benefits of using threads? (1 Point)

☐	Economy, as context switching is cheaper for threads
☐	Scalability, which is important for utilizing modern CPU architectures
☐	Resource sharing within a process
☐	Execution order is trivial when using multiple threads
☐	Responsiveness, which is important for user interfaces

2.2 Which of the following are difficulties when utilizing multiple threads? (1 Point)

☐	Dividing workload between threads
☐	Data dependencies between threads
☐	Verification and validation
☐	Storing and splitting the data between threads
☐	Balancing workload between threads

2.3 What is true about thread cancellation? (1 Point)

☐	Asynchronous cancellation terminates the target thread immediately
☐	Deferred cancellation checks the target thread periodically if it should be cancelled
☐	Thread cancellation occurs only when the thread is finished with its execution
☐	Thread cancellation is disabled by default.
☐	A thread cannot disable its cancellation.

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2.4 What is true about Amdahl's law? (1 Point)

☐	The more serial part a program has, the more it will scale with more processor cores.
☐	The expected speedup is smaller or equivalent to 1 / (serial_portion + (1-serial_portion)/number_of_processing_cores).
☐	Doubling the number of processors can yield up to 33.7% speedup according to the law.
☐	Independent of how your program works, there will be no speedup when increasing the number of processors over 256.
☐	Amdahl's law gives an upper limit on how much speedup we can expect of program using multiple processors when more processors are added to the system.

2.5 What is true about the Windows Thread implementation? (1 Point)

☐	Uses one single parameter for the PID pointer.
☐	Uses less parameters for thread creation than Java
☐	Uses less parameters for thread creation than C++11 and onward
☐	Still in use for C programs
☐	Is a specification but not an implementation

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2.6 Draw a comparison between a single-threaded and multithreaded process, displaying the inner structure of both. Make sure to label the necessary parts accordingly. (You can draw this on an extra sheet) (3 Points).

2.7 Draw the many-to-many multithreading model. Make sure to label the necessary parts accordingly. (You can draw this on an extra sheet) (2 Points)

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3 Process scheduling (10 Points)

3.1 What is true about scheduling? (1 Point)

☐	With non-preemptive scheduling, the CPU can be taken away from a process without the cooperation of the given process.
☐	The short-term scheduler selects from among the processes in the job queue.
☐	The ready queue is managed by long-term scheduling.
☐	CPU scheduling only takes place when a process terminates.
☐	Both preemptive and non-preemptive scheduling can be present in the same OS.

3.2 What is true about the scheduling goals of interactive processes? (1 Point)

☐	Minimize average response time
☐	Complete process by given deadline
☐	The solution should scale
☐	CPU utilization should be maximal
☐	The solution should be fair amongst processes

3.3 What is true about the evaluation of scheduling algorithms? (1 Point)

☐	Simulations can be done on a whiteboard
☐	Implementing a scheduling algorithm within a real system is usually the most expensive
☐	Analytical evaluations require mathematical models for their input
☐	Deterministic modeling can be time-consuming for a project
☐	Compute-deterministic evaluation gives results for every possible workload input

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3.4 What is true about non-homogenous multiprocessing? (1 Point)

☐	All CPU cores are alike within the CPU
☐	The instruction set of the CPU cores must be the same within the CPU
☐	Can create issues with CPU scheduling that can only be solved on OS level
☐	It is a common solution on servers to increase performance
☐	It is an uncommon concept that is only important for legacy systems as it makes software development harder

3.5 Scheduling algorithms

Assume the following processes arrive for execution at the indicated time with the specified priority and the length of their CPU-burst time given in milliseconds. (You can give your answer on the extra sheet)

Process	Burst time (ms)	Priority	Arrival time (ms)
P1	3	2	0
P2	2	1	1
P3	1	3	2
P4	1	4	2
P5	3	1	3

3.5.1 Give a Gantt chart illustrating the execution of these processes using FCFS, Round Robin (quantum=3), and Priority (Non-pre-emptive). (3 Points)

3.5.2 Calculate the average waiting time for each of the above scheduling algorithms. (3 Points)

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4 Synchronization (10 Points)

4.1 If you have two threads modifying the same variable int var = 4 in parallel, with their respective code being (without synchronization) (1 Point):

Thread A **Thread B**

var=var+2 **var=var-1**

☐	It is possible to get var = 6 as a result
☐	It is possible to get var = 3 as a result
☐	It is possible to get var = 5 as a result.
☐	It is possible to get var = 2 as a result
☐	The result of the variable var can be different after each execution of the above code

4.2 Which of the following criteria should a proper solution to the critical-section problem fulfill? (1 Point)

☐	Bounded waiting
☐	Progress
☐	Mutual exclusion
☐	Enrollment
☐	Wondering philosophers

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4.3 What is true about synchronization hardware? (1 Point)

☐	Disabling interrupts is an efficient solution on modern hardware for synchronization
☐	It is a thing of the past
☐	Modern machines do not need to provide atomic hardware instructions
☐	Synchronization hardware uses keys
☐	Disabling interrupts is appropriate for multiprocessor systems.

4.4 What is true about the bounded-buffer classical problem? (1 Point)

☐	It is sometimes called the consumers' problem.
☐	It has two kinds of processes: a consumer and a buffer.
☐	Uses three types of semaphores: Mutex, full, and empty.
☐	Uses a buffer
☐	Regarded as a classical problem where the cooperating processes must follow each other in strict order.

4.5 What is true about the readers-writers classical problem? (1 Point)

☐	Is a form of selective mutual exclusion, as some processes (i.e., readers) can be in a critical section simultaneously, but not others.
☐	Has a variant prioritizing writers
☐	Has a variant prioritizing readers
☐	Depending on the implemented solution, starvation is possibly an issue.
☐	Writers both read and write the data

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4.6 What is true about the dining philosophers classical problem? (1 Point)

☐	It represents a problem where processes need to access multiple resources at the same time to perform their goal.
☐	Platon has the ability to use the cave to take all resources.
☐	Deadlocks can be handled with asymmetric solutions depending on the number of the philosopher.
☐	Philosophers in the problem are either eating or drinking fine vine
☐	The solution only works with exactly five philosophers.

4.7 What happens if you use a semaphore incorrectly? (2 Points)

1) Signal (mutex) ... wait (mutex)
2) Wait (mutex) ... wait (mutex).

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4.8 Draw the general inner structure of a process containing a critical section. Make sure to label the necessary parts accordingly. (2 Points)

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5 Deadlocks (10 Points)

5.1 What are the common methods for handling deadlocks? (1 Point)

☐	Ignore that the problem exists
☐	Using a heterogeneous CPU architecture
☐	Allow the system to recover from deadlocks
☐	Ensure that the system will never enter a deadlock
☐	Decreasing the operating voltage of the CPU (undervolting) to increase the power draw headroom available.

5.2 Which of the following conditions must hold simultaneously for a deadlock to arise? (1 Point)

☐	Mutual exclusion
☐	No preemption
☐	Circular wait
☐	Hold and wait
☐	Enrollment

5.3 When recovering from a deadlock and aborting one process at a time (selecting them as victims), which of the following factors can be considered to choose a potential process as a victim? (1 Point)

☐	How long the user has been logged on
☐	How many victims are needed
☐	Resources needed by the process to complete
☐	Priority of the process
☐	Type of process (interactive or batch)

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5.4 Draw an example of a resource allocation graph (3 Points)

5.4.1 Containing a cycle and a deadlock

5.4.2 Containing a cycle but not a deadlock

Make sure to use the correct notation and label the necessary parts accordingly. (You can give your answer on the extra sheet)

5.5 Apply the banker's algorithm to the example below and determine if a safe sequence exists. The total amount the resource are: A=5, B=7, C=6. Write down the intermediate results for each step. (4 Points) (You can give your answer on the extra sheet)

	Allocation			Max		
	A	B	C	A	B	C
P0	1	1	1	2	2	2
P1	2	1	3	4	2	3
P2	1	1	1	4	3	4
P3	0	2	0	1	2	1
P4	1	0	1	1	1	1

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Part 2 (BUTS):

- describe and compare terms, techniques, and algorithms in primary memory management, for example addressing, address binding, paging, segmentation, and virtual memory;
- describe and compare terms, techniques, and algorithms in secondary memory management, for example file allocation and scheduling of disc operations;
- discuss the problems of protection and security in modern operating systems

6 Memory management (10 Points)

6.1 Which of the following statements about memory management are true? (1 point)

☐	Windows DLL and Linux dynamic shared objects are examples of execution time address binding.
☐	User mode processes (programs) can adjust the base and limit registers defining the space the process occupies in memory.
☐	Compile time address binding permits running processes to be moved in memory.
☐	A logical address is a memory address used by the CPU.
☐	If code is compiled with relocatable addresses the operating system can choose where to load a process into memory.

6.2 Which of the following statements about memory management are true? (1 point)

☐	A single process always uses contiguous frames in physical memory.
☐	Memory protection schemes cannot be implemented using page tables.
☐	Searches (look-ups) in a translation look aside buffer (TLB) depend on the number of entries in the TLB and have a computational complexity of O(n).
☐	Copy on write allows processes to share pages with child processes when the child process is forked.
☐	For a single-level page table, each data access in a program requires two memory accesses.

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6.3 Which of the following statements about segmentation are true? (1 point)

☐	There is no external fragmentation when using segmentation to manage memory
☐	A segment may contain data shared between processes.
☐	A virtual address consists of the tuple <segment_number, offset>.
☐	Memory protection policies can be implemented for each segment.
☐	Memory management using segmentation is a dynamic storage allocation problem.

6.4 Which of following statements about contiguous memory allocation are true? (1 point)

☐	Operating system processes are loaded into high memory addresses.
☐	The worst fit algorithm assigns processes to the smallest available memory space.
☐	Internal fragmentation is guaranteed in contiguous memory allocation schemes.
☐	When a process exits, the memory it was using is combined with memory in any adjacent unused memory (or holes) to create a new hole or free partition to be allocated to a new process.
☐	To implement the best-fit algorithm the operating system must maintain a sorted list of memory holes.

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6.5 Given a page size of 4096 bytes (4KB) and a process that requests 12596 bytes in memory:
1. Calculate how many pages of memory the operating system allocates to the process (1 point)
2. Calculate the number of bytes of memory in the internal fragment (1 point)

Show the steps in your calculations.

6.6 An operating system could swap an entire process out to a backing store (disk) so that another process could be swapped into memory to be executed. Explain why this is not a good approach to memory management. (2 Points)

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6.7 Processes can share pages in physical memory. Draw a diagram showing logical memory and page tables for two processes, and physical memory that illustrates how the processes share two code frames, and have three pages of data each. (2 Points)

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7 Virtual memory (10 points)

7.1 Which of the following statements about virtual memory management are true? (1 point)

☐	A page fault occurs when a requested virtual address is not found in memory.
☐	A hashed page table generally requires fewer memory accesses in operation than a nested hierarchical page table.
☐	A page fault may mask (hide) an illegal memory access by a process.
☐	In an operating system using a single level page table, each data access in a program requires three memory accesses.
☐	Demand paging ensures that all the code and data in a program is loaded into memory when the program starts.

7.2 Which of the following statements about frame allocation are correct? (1 point)

☐	Local allocation of frames results in highly variable process execution time each time a process is run.
☐	A high page fault rate can cause the operating system to spend more time replacing pages in memory than performing computation.
☐	Global allocation of frames means that each process is assigned a fixed number of frames when the process starts.
☐	The Flashman frame allocation algorithm provides a solution that prevents thrashing.
☐	Global allocation of frames gives improved program throughput and is thus appropriate for hard real-time operating systems.

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7.3 Which of the following statements about page replacement algorithms are true? (1 point)

☐	Belady's Anomaly is observed for some reference strings when the number of frames allocated to a process is increased when using the least recently used (LRU) page replacement algorithm.
☐	Modified frames are selected as victim frames before unmodified frames in the enhanced second chance algorithm.
☐	The second chance and enhanced second chance algorithms are approximations of the least recently used (LRU) algorithm.
☐	Page buffering can be used to cache pages so that recently used pages can be reloaded more quickly.
☐	The OPT page replacement algorithm is implemented in quantum computers.

7.4 A transition lookaside buffer (TLB) is a hardware device used to implement memory paging.

a. What does a TLB do? (1 point)
b. How does a TLB search for entries? (1 point)
c. Why are TLBs too small to map the whole memory? (1 point)

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7.5 Given the page reference string: 7, 0, 4, 2, 6, 3, 3, 6, 1, 4, 3, 3, 2, 6, 1, 1, 2, 5, 7, 2

Assuming demand paging with a page table of three frames, how many page faults would occur with the following replacement algorithms?

a. LRU replacement (2 points)

b. Optimal replacement (2 points)

For each algorithm, write a page table showing the state of the page table following each request in the reference string. Clearly mark each request that causes a page fault, and state the total number of page faults for each algorithm.

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8 File systems (10 Points)

8.1 Which of the following statements about files and directories are true? (1 point)

☐	An operating system needs a policy for deleting shared files.
☐	A file owned by the root user and root group with the Unix file permissions 700 (in octal) can not be read by any other system user.
☐	Operating systems generally interpret file contents as either human-readable text or a binary format.
☐	The operating system's seek instruction places the read/write pointer at a specific location in a file.
☐	A directory consists of a list of links to files and other directories.

8.2 Which of the following statements are true about disk scheduling? (1 point)

☐	Disk scheduling algorithms are constrained by the physical properties of hard disk drives.
☐	The shortest seek time first (SSTF) algorithm can lead to starvation for some processes.
☐	C-Look and C-Scan read and write data requests when the head moves in both directions.
☐	FIFO is an efficient disk scheduling algorithm.
☐	The Look algorithms reduce the number of sectors the head visits compared to the Scan family of algorithms.

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8.3 Which of the following statements about disk drives are true? (1 point)

☐	A disk drive can only read from one cylinder at a time.
☐	Striping is used in RAID systems as a means of error detection.
☐	RAID is used to reduce the consequences of disk failure.
☐	Rotational latency refers to the time taken for the read/write head to move between cylinders on a disk drive.
☐	The free-space list is created and used by the disk controller.

8.4 Indexed allocation of file blocks provides good random access to file contents compared to linked allocation. Briefly describe three disadvantages of indexed allocation (1 point each)

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8.5 Operating systems use file control blocks containing metadata about each file. Name four items of metadata you would expect to find in a file control block and briefly explain how each item metadata is used (1 point each)

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9 Protection and security (10 Points)

9.1 Information security concerns threats to the confidentiality, integrity, and availability of data. Which of the following statements are true? (1 point)

☐	A ransomware attack violates the confidentiality, integrity, and availability of data.
☐	Authorisation is used to ensure access to the right resource.
☐	The following real scenario is an attack on the integrity of data: "Hackers stole Pfizer and BioNTech data from the European Medicines Agency (EMA) and altered it before posting it on the dark web."
☐	An operating system sends encrypted data from a computing system to the operating system's developers. This is a threat to the confidentiality of data.
☐	Redundant data centers do not support the availability of data.

9.2 Which of the following statements about network security are true? (1 point)

☐	A firewall can prevent a distributed denial of service (DoS) attack.
☐	Carol uses both theft of service and denial of service attacks when she steals Alice's bus ticket.
☐	Physical security of data centers is an important component of network security.
☐	A DMZ (demilitarised zone) describes part of a network containing internet facing servers that is isolated from the rest of the company's internal network.
☐	A firewall can protect a network against malicious actions in tunnelled traffic.

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9.3 Which of the following statements about cryptography are correct? (1 Points)

☐	Public key cryptography is an asymmetric encryption algorithm.
☐	For network security reasons, a company firewall acts as a proxy server for HTTPS web page requests by spoofing public security certificates so that HTTPS traffic leaving and entering the company network can be decrypted, inspected, and re-encrypted. This is an example of a man-in-the-middle attack.
☐	When using a digital signature, the sender uses their public key to encrypt a message and the receiver uses the sender's private key to decrypt the message and confirm the sender's identity.
☐	Alice locks her computer then leaves the room. While she is away, Bob finds a post-it note under Alice's desk with her password on it. Bob then uses Alice's computer to send an insulting email to a senior manager. Bob's actions are an example of a masquerade attack.
☐	Block encryption algorithms such as DES are computationally expensive compared to public key cryptography.

9.4 Computer security must be implemented in each of the four levels to be effective. Name the four levels and give a brief (one to two sentence) description of the security measures and threats at each level (1 point for each correct level and description).

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9.5 Authentication and authorisation are used in the AAA framework. Explain the difference between authentication and authorization and how both support security implementation. (3 points)