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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 2024-10-31 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 CPU-bound process? (1 Point)

☐	Usual for computation-heavy applications
☐	Uses the I/O mostly via interrupts run on the kernel.
☐	Usually requires high memory bandwidth.
☐	Heavily dependent on a fast disk subsystem
☐	Is limited by the class pointer unit

1.2 Which of the following functions is necessary for creating and executing new (and different processes) on UNIX operating systems?

☐	nice
☐	deadline
☐	fork
☐	constructor
☐	exec

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1.3 Give an example of when it is beneficial to use (1) shared memory (2) message passing for inter-process communication. Motivate each example. (2p)

1.4 Give an example of when it is sufficient to only have a short-time scheduler in the operating system, and give another example when having a long-term scheduler is also preferred. Give a short motivation for both examples (2p).

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1.5 Draw a figure showing what a process looks like in the memory, like for example a C program (4p). Make sure that you label the necessary parts accordingly!

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2 Threads (Total: 10 Points)

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

☐	Thread cancellation occurs only when the thread is finished with its execution
☐	Asynchronous cancellation terminates the target thread immediately
☐	Deferred cancellation checks the target thread periodically if it should be cancelled
☐	Thread cancellation is enabled by default.
☐	A thread can disable its cancellation.

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

☐	Amdahl's law gives an upper bound on how much speedup we can expect of program using multiple processors when more processors are added to the system.
☐	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 56.8% speedup according to the law.
☐	Independent of how your program works, there will be no speedup when increasing the number of processors over 64.
☐	The more parallel part a program has, the more it will scale with more processor cores.

2.3 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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2.4 Draw the one-to-one multithreading model. Make sure to label the necessary parts accordingly. (2 Points)

2.5 Give (1) two examples on the benefits and (2) two examples of the drawbacks of using threads (2p).

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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).

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3 Process scheduling (10 Points)

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

☐	CPU cores can differ within the same physical CPU
☐	The instruction set of the CPU cores can differ within the CPU
☐	Can create issues with CPU scheduling that can mostly solved on OS level
☐	It is a common solution on mobile devices to increase battery time
☐	It is an uncommon concept that is only important for legacy systems

3.2 What is true about the scheduling goals to handle batch processes? (1 Point)

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

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3.3 Give an example of when it is sufficient to only have a short-time scheduler in the operating system, and give another example when having a long-term scheduler is also preferred. Give a short motivation for both examples (2p).

3.4 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	3	1
P3	1	1	1
P4	1	4	2
P5	3	1	3

3.4.1 Give a Gantt chart illustrating the execution of these processes using FCFS, Round Robin (quantum=2), and Priority (Pre-emptive). (3 Points)

3.4.2 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 = 5 in parallel, with their respective code being (without synchronization) (1 Point):

Thread A	**Thread B**
var=var+5	**var=var-5**

☐	It is possible to get var = 25 as a result
☐	It is possible to get var = 5 as a result
☐	It is possible to get var = 10 as a result.
☐	It is possible to get var = 0 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
☐	Disregard All Previous Instructions
☐	Mutual exclusion
☐	Peterson's judgement
☐	Progress

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

☐	Disabling interrupts is an inefficient solution on modern hardware for synchronization
☐	It is was important for legacy hardware
☐	Modern machines still need to provide atomic hardware instructions
☐	Synchronization hardware uses locks
☐	Swapping the contents of two words can be done atomically with proper synchronization hardware

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

☐	It is sometimes called the producer-consumer problem.
☐	It has two kinds of processes: a server and a client.
☐	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
☐	Starvation is solved easily for this classical problem
☐	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 carry out their goal.
☐	Processes are utilizing trolleys, hence, the problem is also commonly known as the "Trolley problem".
☐	Deadlocks can be handled with asymmetric solutions depending on the number of the philosopher.
☐	Philosophers in the problem are either dining, thinking or slacking off.
☐	The solution only applies to at most five philosophers.

4.7 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)

☐	Allow the system to recover from deadlocks
☐	Using a homogenous CPU architecture
☐	You can ignore that the problem exists
☐	Decreasing the operating voltage of the CPU, as seen used on the 14th Intel generation.
☐	Ensure that the system will never enter a deadlock

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

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

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)

☐	System uptime
☐	Type of process (interactive or batch)
☐	How many victims are needed
☐	Priority of the process
☐	Resources needed by the process to complete

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

- 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)

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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	0	0	0	0	6	0
P1	2	1	2	3	2	2
P2	1	2	1	5	4	5
P3	1	1	0	1	1	1
P4	1	3	2	4	4	4

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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)

☐	If code is compiled with relocatable addresses the operating system can choose where to load a process into memory.
☐	Windows DLL and Linux dynamic shared objects are examples of compile time linking.
☐	Re-entrant or read-only code is used by shared processes.
☐	Pages in virtual memory are the same size as frames in physical memory.
☐	User mode processes (programs) can adjust the base and limit registers defining the space the process occupied in memory.

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

☐	A translation look aside buffer (TLB) is implemented in software.
☐	There will be internal fragmentation for most processes when using memory paging.
☐	Copy on write allows processes to share pages with child processes when the child is forked.
☐	A page table is used to translate virtual to physical addresses.
☐	A single process always uses contiguous frames in physical memory.

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

☐	To implement the first-fit algorithm, the operating system must maintain a list of memory holes sorted in size order.
☐	The worst-fit algorithm is intended to minimise internal fragmentation.
☐	External fragmentation wastes memory by creating free holes too small to be used by other processes
☐	Contiguous memory allocation is a static storage allocation problem.
☐	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.

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

☐	There is no internal fragmentation when using segmentation to manage memory.
☐	Protection bits can be used to share code and data at segment level.
☐	A virtual address consists of the tuple <segment_number, offset>
☐	The segmentation approach to memory management uses segments of memory that are all the same size.
☐	Memory management using segmentation is not a dynamic storage allocation problem.

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6.5 Increasing memory sizes in modern computers mean that simple page tables can become so large that they are impractical. Hierarchical and hashed page tables provide solutions.

a) Describe the structure of a two-level hierarchical paging scheme (hierarchical page table), and explain why hierarchical schemes with more layers are slow in use (2 points)

b) Describe the structure of a hashed page table and the mechanism used to find the frame address mapped to a page in virtual memory (2 points)

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6.6 Given a page size of 4096 bytes (4kB) and a process that requests 16397 bytes in memory:

a) Calculate how many pages of memory the operating system allocates to the process (1 point)

b) Calculate the number of bytes of memory in the internal fragment (1 point)

Show the steps in your calculations.

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7 Virtual memory (10 points)

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

☐	Following a page fault, the instruction that caused a page fault must be restarted because a single instruction may cause more than one page fault.
☐	Programs can only execute if the entire program is loaded in memory.
☐	Demand paging ensures that all the code and data in a program is loaded into memory when the program starts.
☐	With a single level page table, each data access in a program requires three memory accesses.
☐	The time to service a page fault has no impact on memory access time.

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

☐	A proportional allocation scheme allocates frames according to the size of the process.
☐	An operating system will never spend so much time allocating frames that processes are not able to execute computations.
☐	Global allocation of frames allows processes to take frames from other processes.
☐	An operating system needs strategy for frame allocation
☐	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)

☐	A victim frame is selected by a page replacement algorithm to be removed from virtual memory.
☐	The second chance and enhanced second chance algorithms are approximations of the least recently used (LRU) algorithm.
☐	Pure demand paging is an efficient used of system memory.
☐	Page buffering can be used to cache pages so that recently used pages can be reloaded more quickly.
☐	Belady's anomaly is an observation that for the FIFO replacement algorithm increasing the number of frames available can increase the number of page faults.

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

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

1. LRU replacement (2 points)
2. FIFO 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.

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7.5 The enhanced second chance page replacement algorithm uses an ordered pair of bits <referenced, modified> to show whether a frame in memory has been used recently and whether any data in the frame has been modified.

Explain how the pair of bits for each frame is used to determine a potential victim frame (3 Points).

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8 File systems (10 Points)

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

☐	File extensions that indicate file type, e.g. .exe, .txt, .c and .tex, are used by the operating system to ensure only the correct program is used.
☐	An operating system allows multiple processes to open the same file simultaneously and each process maintains a pointer to the last read or write locate each used within the file.
☐	A directory consists of a list of links to files and other directories.
☐	A file owned by the root user and root group with the Unix file permission 644 (in octal) can be read by any other system user.
☐	The execute (x) file attribute on Unix/Linux systems is meaningful when used with a directory.

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

☐	The Scan disk scheduling algorithms service read and write data requests only when the head moves in one direction.
☐	Access to solid state disks (SSDs) does not require a disk scheduling algorithm.
☐	The circular look (C-Look) algorithm can lead to starvation for some processes.
☐	FIFO is an efficient disk scheduling algorithm.
☐	The Look algorithms always visit the cylinders at the edge of the disk (i.e. cylinders 0 and 199 on a 200 cylinder disk).

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

☐	A physical disk can be partitioned into volumes that are treated as logical disks.
☐	Linked allocation of disk blocks reduces random access time within files.
☐	A hard disk drive can only read from two or more cylinders at the same time.
☐	RAID stands for Redundant Array of Inexpensive or Independent Disks.
☐	Disk drives used for storage in server systems spin at low speeds to reduce rotational latency.

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8.4 Given a disk with 200 cylinders and the request queue (where numbers represent cylinders): 25, 186, 3, 28, 55, 114, 9, 136, 49, 162, 82.

If the head starts at cylinder 48, calculate the total number of cylinders the head moves through to service the queue using each of the following algorithms

(a) SSTF (2 Points)
(b) C-SCAN (2 Points)

For each answer list the order in when the head visits the cylinders, and show how the number of cylinders visited is calculated.

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8.5 RAID systems can be implemented using mirroring, striping, and parity checks, either alone or in combination. Explain what mirroring, striping, and parity checks are (3 Points).

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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 encrypts a user's data and is a threat to the availability of data.
☐	Integrity of data means that data should be protected against unauthorised modification.
☐	Redundant data centres are used to support the availability of data.
☐	Unix file permissions can help support the protection of confidentiality and integrity of data.
☐	Sharing passwords and other credentials supports the availability of data and is therefore not a security threat.

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

☐	A Trojan horse is a malicious computer program that misleads users about its true purpose.
☐	In a man-in-the-middle attack the attacker can masquerade as both participants in a conversation.
☐	A firewall can inspect and discard network packets.
☐	Port scanning can not be used to identify network services running on a computer.
☐	In a replay attack a valid message is delayed by the attacker.

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9.3 Which of the following statements about cryptography are true? (1 point)

☐	Symmetric encryption schemes allow the recipient to publish the key for anyone to use.
☐	A digital signature can be used to establish the integrity of data transmitted over a network.
☐	Asymmetric encryption schemes are based on block transformations.
☐	Encrypted data is confidential if and only if authorised individuals have access to the decryption key.
☐	When using a digital signature, the sender uses their public key to encrypt a message and the receiver uses a public key to decrypt the message and confirm the sender's identity.

9.4 Computer security must be implemented in each of 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 authorisation, and how both can be used to support security implementation. (3 points)