UNIVERSITY
OF SKÖVDE

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 2024-12-18 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 (if not answering on the exam sheet directly).
- ☒ 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 the parts 1-2
ECTS B >=72.5% of points on the whole exam AND >= 25% on all of the parts 1-2
ECTS C >=65% of points on the whole exam AND >= 25% on all of the parts 1-2
ECTS D >= 57.5% of points on the whole exam AND >= 25% on all of the parts 1-2
ECTS E >= 50% of points on the whole exam AND >= 25% on all of the parts 1-2
ECTS F <50% of points on the whole exam OR <25% on any of parts 1-2 on their own

UNIVERSITY
OF SKÖVDE

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 have your computations present. Computations are preferably answered on the writing sheets. For the figures, please make sure that all necessary parts are present.

You must write your name and (Swedish) person number on all answered sheets, even on the exam sheets.

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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 Which of the following busses are necessary for communication between the CPU and the memory? (1 Point)

☐	Memory buffer bus
☐	Address bus
☐	Control bus
☐	Data bus
☐	Instruction bus

1.2 Which of the following functions is necessary for creating and executing new (and different processes) on UNIX operating systems? (1 Point)

☐	getsetpriority
☐	nice
☐	fork
☐	constructor
☐	exec

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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

1.4 Compare the **size** and the **speed** of the following components in the storage-device hierarchy: CPU cache, solid-state drive, main memory, and magnetic tape. You can draw a figure if needed. (2 Points)

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

1.5 Draw a diagram representing which states a process can have (4 Points). Make sure that you include the state transitions too!

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

2 Threads (Total: 10 Points)

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

☐	Amdahl's law only applies to legacy systems.
☐	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 250% speedup according to the law.
☐	Independent of how your program works, there will be no speedup when increasing the number of processors over 16.
☐	The more serial parts a program has, the less it will scale with more processor cores.

2.2 What is true about PThreads? (1 Point)

☐	Is short for preferred threads
☐	Must be always provided at kernel-level
☐	Concerns only the specification
☐	Commonly used
☐	Must be always provided at user-level

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

☐	Uses one single parameter for the PID
☐	Uses more parameters for thread creation than Java
☐	Uses more parameters for thread creation than C++11 and onward
☐	Still in use, for example, for C programs
☐	It is an actual implementation and not just a specification

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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

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

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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).

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

3 Process scheduling (10 Points)

3.1 What is true about 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 the OS level
☐	It is a standard 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 for handling interactive processes? (1 Point)

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

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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.

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

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

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

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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
var=var+3

Thread B
var=var-3

☐	It is possible to get var = 2 as a result
☐	It is possible to get var = 8 as a result
☐	It is possible to get var = 5 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
☐	Suspension of disbelief
☐	Mutual exclusion
☐	Progress
☐	Use hex encoding to answer

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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

☐	Disabling interrupts is an inefficient solution on modern hardware for synchronization
☐	It was only important for legacy hardware
☐	Disabling interrupts is appropriate for multiprocessor systems.
☐	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 readers-writers problem.
☐	It has two kinds of processes: a reader and a writer.
☐	Uses three types of semaphores: Mutex, full, and empty.
☐	Uses a printer
☐	Regarded as a classical problem where the cooperating processes must follow each other in strict order.

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

☐	A version of the problem with uncooperative philosophers (on a ship) is known as the "Vessel of Hatred."
☐	It represents a problem where processes need to access multiple resources simultaneously to carry out their goal.
☐	Deadlocks can be easily handled with symmetric solutions.
☐	Philosophers in the problem are either dining, thinking, or bathing.
☐	The solution only applies to at most four philosophers.

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

4.7 Describe what happens if you use a semaphore incorrectly. (3 Points)

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

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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 heterogenous CPU architecture
☐	Ignore that the problem exists
☐	Ensure that the system will never enter a deadlock
☐	*#declare DEADLOCK PROHIBITED* in the kernel

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

☐	Hold and wait
☐	Mutual exclusion
☐	Circular wait
☐	No preemption
☐	First in, first out

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 when choosing a potential process as a victim? (1 Point)

☐	Type of process (interactive or batch)
☐	Priority of the process
☐	How many victims are needed
☐	System uptime
☐	User login time

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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)

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

5.5 Apply the banker's algorithm to the example below and determine if a safe sequence exists. The total amount of the resource are: A=7, B=7, C=7. 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	0	0	1	4	0
P1	2	2	2	3	2	2
P2	1	2	1	5	4	6
P3	1	1	0	3	1	1
P4	1	2	2	5	4	4

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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)

☐	User mode processes (programs) can not adjust the base and limit registers defining the space the process occupies in memory.
☐	If code is compiled with relocatable addresses, the program can choose where to load itself into memory.
☐	At initialisation, a user process (program) is added to a queue for the operating system to load the process into memory.
☐	Compile time address binding can be used for systems without operating systems such as embedded devices.
☐	Pages in virtual memory are always smaller than frames in physical memory.

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

☐	Memory pages are fixed size blocks of memory.
☐	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), where n represents the number of page addresses stored in the TLB.
☐	There will be external fragmentation for most processes when using memory paging.
☐	Memory protection schemes can be implemented in page tables by adding bits to each entry to indicate whether the frame is read-only, executable, and so on.
☐	Inverted page tables can be used to reduce the amount of memory required for page table.

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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

☐	Operating system processes are loaded into low memory addresses.
☐	The multi-fit algorithm provides the optimal solution to contiguous memory allocation.
☐	The best-fit algorithm finds an available memory hole that creates the smallest possible external fragment,
☐	The worst fit algorithm assigns processes to the largest available memory space.
☐	Internal fragmentation is guaranteed in contiguous memory allocation schemes.

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

6.4 Operating systems use both physical and virtual (logical) memory addresses.

i) Define a logical (virtual) memory address (1 Point);

ii) Define a physical memory address (1 Point); and

iii) Identify three reasons virtual (logical) memory is used. (3 Points)

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

6.5 Explain what execution time binding is and give an example of how it is used in a modern operating system such as Linux or Windows. (2 Points)

UNIVERSITY
OF SKÖVDE

Name: _____ Person number: _____

7 Virtual memory (10 points)

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

☐	Dirty victim frames are always written to the backing store when they are swapped out.
☐	A page fault occurs when the wrong page is found in memory.
☐	Code needs to be in memory to execute, but an entire program does not.
☐	A hashed page table generally requires more memory accesses in operation than a hierarchical page table.
☐	Page fault service time is orders of magnitude greater than memory access time.

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

☐	In a proportional allocation scheme the number of frames allocated to a process changes in relation to the number of processes loaded in memory.
☐	Thrashing occurs when there is a high page fault rate and the operating system spends more time allocating frames than performing computation.
☐	Equal allocation of frames reduces the number of page faults for large programs.
☐	Local replacement of frames means that each process may only use a set of frames allocated to it.
☐	Process execution time can vary greatly when using a global frame allocation strategy.

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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

☐	The most frequently used (MFU) algorithm considers pages with least use were most recently loaded into memory and are likely to be used soon.
☐	The optimal page replacement algorithm (OPT) is implemented in Windows 11.
☐	Modified frames are selected as victim frames before unmodified frames in the enhanced second chance algorithm.
☐	Belady's anomaly is an observation that for the LRU page replacement algorithm that increasing the number of frames available can increase the number of page faults.
☐	OPT and LRU are stack-based algorithms.

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

7.4 In a paged memory system a process executes the code compiled from the following C statement:

```
elapsed_time = end_time - start_time;
```

i) Assuming that all the variables have been declared and memory assigned to hold the values, explain how many page faults might occur during execution of the instruction and why? (2 Points)

ii) Explain briefly why the total number of possible page faults you identified is unlikely to occur when the statement is executed in a modern operating system? (1 Point)

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

7.5 Copy on write (CoW) is used to improve the speed and efficiency of forking processes.

i) Explain how CoW works when a child process is created, and what happens when either the parent or child process modifies data. (3 Points)

ii) Explain the benefits of using CoW. (1 Point)

*(Answers containing a diagram **only** will be marked as 0.)*

UNIVERSITY
OF SKÖVDE

Name: _____ Person number: _____

8 File systems (10 Points)

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

☐	The operating system's seek instruction on a file is used to find files in storage.
☐	Operating systems generally interpret file contents as either human readable text, or a binary format.
☐	In a tree file structure all files have unique names.
☐	Open files are never cached in memory.
☐	An operating system needs a policy for deleting shared files.

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

☐	The analysis of a disk scheduling algorithm is true for one or many platters.
☐	The shortest seek time first (SSTF) algorithm can lead to starvation for some processes.
☐	First come first served (FCFS) is an efficient disk scheduling algorithm.
☐	The C-Look and C-Scan algorithms read and write data requests when the head moves in only one direction.
☐	Disk scheduling algorithms are used only when there is a queue of requests.

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

8.3 Which of the following statements about disk drives and file systems are true? (1 Point)

☐	Each disk partition includes data for free space management.
☐	A disk drive can only read from one cylinder at a time.
☐	Striping is used in RAID systems to support error detection and correction.
☐	Using a linked allocation scheme for file blocks reduces random access times within the file.
☐	A bit map or bit vector can be used to track available block or clusters on disks.

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

8.4 Disk scheduling algorithms are constrained by the physical components of a rotating disk and the mechanism used to move the heads. Solid state drives (SSD) such as USB drives and NVMe drives do not have moving parts.

i) What disk scheduling algorithm would be suitable for an SSD? (1 Point)

ii) Explain why the algorithm is suitable for SSDs and whether there are any opportunities to optimise the algorithm for SSDs. (2 Points)

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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)

☐	Role based access control can be used to implement the principle of least privilege.
☐	A capability list represents a column in an access matrix.
☐	Integrity of data means that data should be protected against unauthorised modification.
☐	Authorisation is used to ensure access to the right resource.
☐	Humans are the strongest part of any security system.

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

☐	The physical security of data centres is used to support network security.
☐	A buffer overflow is an error on a disk that can be exploited to execute malicious code.
☐	A public key can be distributed in cleartext to anyone who wants to communicate with holder of the private key
☐	A firewall cannot prevent a denial of service (DoS) attack.
☐	A DMZ describes a network containing internet facing servers that is isolated from a company's internal network.

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

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

☐	Cryptography can not be used to support identification of the source of a message sent over a network.
☐	Carol has a copy of Bob's public key and is able to read the contents of a message Alice has encrypted with Bob's public key and sent to Bob.
☐	Determining the prime factors of very large numbers is computationally trivial.
☐	A digital signature is used to establish the confidentiality of data transmitted over a network.
☐	Symmetric encryption schemes require that keys are distributed securely.

9.4 Draw an access matrix for four domains and three objects (O1, O2 and O3) where one domain can read and write the object O1, another domain can read all three objects, the third domain is unable to access 01, 02 and 03, but can use a printer, and the fourth domain can read and read and write O2 and O3. (4 Points)

UNIVERSITY
OF SKÖVDE

Name: _____Person number: _____

9.5 Public key cryptography uses an asymmetric encryption scheme with a pair of keys – a public key and a private key. The use of public key cryptography is supported by public key infrastructure (PKI) include the use of certification authorities and digital certificates.

i) What is a digital certificate? (1 Point)

ii) Explain the problem that a digital certificate solves and how it solves the problem? (2 Points)