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Times: Thursday 2018-03-01 at 19:00 to 20:50 (7 to 8:50PM)

Duration: 1 hour 50 minutes (110 minutes)

Exam ID: 3703176

Sections: CS 350 LEC 001-004

Instructors: Ali Mashtizadeh, Lesley Ann Istead



Examination Midterm Winter 2018 CS 350

### Closed Book

Candidates may bring no aids (no calculators).

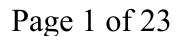
## University of Waterloo CS350 Midterm Examination

Winter 2018

Student Name:	

Closed Book Exam No Additional Materials Allowed

CS 350 Winter 2018 Midterm
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### 1. (12 total marks) True or false.

a MIPS treats all interrupts and exceptions as exceptions.
${\bf b.}$ When implementing a spinlock, ${\bf lw}$ and ${\bf sw}$ are used to test-and-set the lock atomically.
c It is not possible to have consecutive trapframes on a stack.
d A semaphore can allow multiple threads into a critical section.
e The bits used for the segment number limit the size of the segment.
<b>f.</b> Volatile variables guarantee atomicity of loads and stores.
g System calls are exceptions in MIPS.
h All processes terminate by a call to _exit.
i Dynamic relocation is efficient with respect to translation space and time.
$\mathbf{j}$ Address spaces contain but do not use $0x0$ because this address is reserved for NULL.
k Paging eliminates internal fragmentation.
l Paging eliminates external fragmentation.

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2	(11	total	marks)	Short	Answer

a. (3 marks) List three possible sources of race conditions.

**b.** (2 marks) On a multi-CPU system, suppose interrupts are turned OFF and no re-arranging of code is performed. Is this sufficient to prevent race conditions without using synchronization primitives? Why or why not?

c. (2 marks) Suppose a program has a global array of N items. N threads are forked such that thread i only reads/writes array element i. The global array is not used by any other threads. Is synchronization required for this global array? Why or why not?

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d. (5 marks) List the five steps required to implement cv-wait.

e. (2 marks) How are binary semaphores different from locks?

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### 3. (4 total marks)

A process was running user code on the CPU when an interrupt was received. The interrupt is for waitpid. While executing sys\_waitpid there is a timer interrupt. Draw the user and kernel stacks for this process up to and including the point of executing timer\_interrupt\_handler.

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### 4. (5 total marks)

Consider the following pseudo code:

```
Queue carBuffer[N];
Semaphore parkingSpots( N );
Semaphore cars( 0 );

MakeCar()
{
    P( parkingSpots );
        carBuffer.add();
    V( cars );
}

TakeCar()
{
    P( cars );
        carBuffer.pop();
    V( parkingSpots );
}
```

- a. (1 marks) Is there a race condition in this code?
- b. (4 marks) If you answered (a) yes, fix the code. Otherwise, explain why there is no race condition.

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5. (9 total marks)	
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**a.** (6 marks) Consider an implementation of memory segmentation. What would be required to support growing segments? List the steps, remember that there is a maximum segment size.

**b.** (3 marks) What are the problems associated with segmentation?

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### 6. (12 total marks)

A system uses 64 bit physical addresses and 16 bit virtual addresses. Frame and page size is 4KB  $(2^{12} \text{bytes})$ .

- a. (1 mark) How many bits are required for the page offset?
- **b.** (1 mark) How many frames of physical memory are there?
- c. (1 mark) How many pages of virtual memory are there?
- d. (1 mark) How many bits are required for the frame number?
- e. (1 mark) How many bits are required for the virtual page number?
- **f.** (1 mark) Suppose each process used the maximum amount of virtual memory, and, on-demand paging is not used. What is the maximum number of process that could live in physical memory at the same time? (Assume the kernel occupies 0 bytes).
- g. (1 mark) If a process uses 1KB ( $2^{10}$ bytes) of memory for its address space, how much memory is wasted due to internal fragmentation?

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Question	6	continued

h.	(4 marks)	Which	of the	following	virtual	${\rm addresses}$	are	valid	for	a	process	that	uses	the	first
	$0 \to 2^{10} -$	1 bytes	of virt	ual memo:	ry?										

**i.** 0x0000

**ii.** 0xFEE5

**iii.** 0x1234

iv. 0x010A

i. (1 mark) If each entry in the page table is 2<sup>4</sup> bytes, what is the size of the page table?

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#### 7. (6 total marks)

A program has N global queues of equal length M. Suppose we wish to create a function caused AddElement( queue a, queue b, int i) which adds the  $i^{th}$  element of queue a to the  $i^{th}$  element of queue b. Note that a and b must be unique queues.

We want to implement synchronization for **AddElement** such that as many threads as possible may execute **AddElement** concurrently.

A throwaway on reddit suggested that you use N locks—one for each queue and acquire them in increasing order of queue number.

```
void AddElement( queue a, queue b, int element )
{
    if ( a.num < b.num )
    {
        acquire( a.lock );
        acquire( b.lock );
    }
    else
    {
        acquire( b.lock );
        acquire( a.lock );
        acquire( a.lock );
    }
}</pre>
```

- a. (1 mark) What is the maximum number of threads that can execute AddElement concurrently (without a race condition)?
- **b.** (1 mark) Is there a solution that lets more threads execute **AddElement** concurrently (without a race condition)?
- c. (4 marks) If yes, describe that solution. If no, explain why.

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### 8. (6 total marks)

Your employer asks you to implement **bool try\_acquire( lock \* lk )** for locks. This function returns **true** and takes the lock if it is available, or returns **false** if the lock is not available. **try\_acquire** does not force the calling thread to block if the lock is not available. List the steps to implement **try\_acquire**.

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### 9. (8 total marks)

A system uses 32bit physical and virtual addresses and memory segmentation. There are 4 segments, two bits are used for the segment number. The relocation and limit for each of the 4 segments are:

Segment $\#$	Relocation	Limit
0	$0x1000\ 0000$	0x1000
1	$0x8000\ 0000$	0x4000
2	$0x3400\ 0000$	0x0200
3	$0xA000\ 1000$	0xA000

Translate the following addresses from virtual to physical. Clearly indicate what segment each address belongs to.

0x0EA5 EE00

0x00000 0ACE

 $0x3000\ 00C5$ 

0x2000 AFAF