

**New York University**  
**CSCI-UA.0202: Operating Systems (Undergrad): Fall 2021**

**Midterm Exam**

- This exam is **75 minutes**. Stop writing when “time” is called. *You must turn in your exam; we will not collect it.* Do not get up or pack up in the final ten minutes. The instructor will leave the room 78 minutes after the exam begins and will not accept exams outside the room.
- There are **11** problems in this booklet. Many can be answered quickly. Some may be harder than others, and some earn more points than others. You may want to skim all questions before starting.
- **This exam is closed book and notes. You may not use electronics: phones, tablets, calculators, laptops, etc.** You may refer to ONE two-sided 8.5x11” sheet with 10 point or larger Times New Roman font, 1 inch or larger margins, and a maximum of 55 lines per side.
- Do not waste time on arithmetic. Write answers in powers of 2 if necessary.
- If you find a question unclear or ambiguous, be sure to write any assumptions you make.
- Follow the instructions: if they ask you to justify something, explain your reasoning and any important assumptions. **Write brief, precise answers. Rambling brain dumps will not work and will waste time.** Think before you start writing so that you can answer crisply. Be neat. If we can’t understand your answer, we can’t give you credit!
- If the questions impose a sentence limit, we will not read past that limit. In addition, *a response that includes the correct answer, along with irrelevant or incorrect content, will lose points.*
- Don’t linger. If you know the answer, give it, and move on.
- **Write your name and NetId on this cover sheet and on the bottom of every page of the exam.**

*Do not write in the boxes below.*

<b>I (xx/9)</b>	<b>II (xx/10)</b>	<b>III (xx/14)</b>	<b>IV (xx/15)</b>	<b>V (xx/30)</b>	<b>VI (xx/10)</b>	<b>VII (xx/12)</b>	<b>Total (xx/100)</b>

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## I Basics (9 points)

1. [3 points] How many possible settings are there for a bit?
2. [6 points] Consider the following C program; read it carefully:

```
#include <stdio.h>

int b = 4; /* global variable */

void foo(int a) {
    a = 5;
}

void bar(int* a) {
    a = &b;
}

void baz(int* a) {
    *a = 5;
}

int main() {

    int a1 = 1, a2 = 1, a3 = 1;

    foo(a1);

    bar(&a2);

    baz(&a3);

    printf("%d, %d, %d", a1, a2, a3);

    return 0;

}
```

**What does this program print?**

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## II Stacks and assembly (10 points)

3. [10 points] Below is some C code and the corresponding unoptimized assembly code.

```

100  int foo(int a) {
101      int b = a + 1;
102      return b;
103  }
104
105  int main() {
106      int a = 1;
107      int b = foo(a);
108  }

200  foo:
201      pushq   %rbp
202      movq    %rsp, %rbp
203      movq    %rdi, -20(%rbp)
204      movq    -20(%rbp), %rax
205      addq    $1, %rax
206      movq    %rax, -4(%rbp)
207      movq    -4(%rbp), %rax
208      popq   %rbp
209      ret
210
211  main:
212      pushq   %rbp
213      movq    %rsp, %rbp
214      subq    $16, %rsp
215      movq    $1, -8(%rbp)
216      movq    -8(%rbp), %rax
217      movq    %rax, %rdi
218      call   foo
219      movq    %rax, -4(%rbp)
220      movq    $0, %rax
221      ret

```

Below are the meanings of some assembly instructions. This is mostly taken from the class notes.

```

movq A, B    [ move 64-bit data from A to B ]

pushq %rax   [ subq $8, %rsp
               movq %rax, (%rsp) ]

popq %rax    [ movq (%rsp), %rax
               addq $8, %rsp    ]

call 0x5000  [ pushq %rip
               movq $0x5000, %rip ]

ret          [ popq %rip ]

```

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Which assembly instruction will be executed after line 209 (`ret`) executes?

**Write down the line number, for example 200.**

When the process finishes executing line 201 (the first instruction of function `foo`), the top element on the stack is the contents of register `%rbp`.

**What is the element below that one on the stack, meaning the element that would be returned by a second stack pop?**

What are the assembly instructions that represent line 106 (in the C code)?

**Write down the line number or numbers, for example 200 or 200–222.**

During a function call, the caller needs to save call-clobbered (also known as caller-saved) registers. Where is the saving of call-clobbered registers happening in `main()` when calling `foo()`?

**Write down the line number or numbers, for example 200 or 200–222. If there is no such saving in this example, write “none.”**

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### III Concurrent programming (14 points)

4. [10 points] This question asks about coding patterns with multithreaded programming. We have two helper functions or methods:

- `bool safe_to_proceed()` is a function or method that returns a Boolean variable, which is true if it's safe to proceed, and false otherwise.
- `bool progress_is_possible()` is a function or method that returns a Boolean variable, which is true if other threads can (according to the current memory state) possibly make progress, and false otherwise. *This function does not mutate (change) memory state.*

We have a shared mutex `m` and a condition variable `cv`. Assume that each of the patterns below is enclosed in the mutex's acquire/release critical section.

Which of the following patterns abides by the cs202 concurrency commandments and common notions of program correctness? (Hint: the answer is not "None"; you will need to circle at least one of the items.)

**Circle ALL that apply:**

- a    `while (safe_to_proceed())`  
      `cv.wait(&m);`
- b    `while (! safe_to_proceed())`  
      `cv.wait(&m);`
- c    `if (! safe_to_proceed())`  
      `cv.wait(&m);`
- d    `while (progress_is_possible())`  
      `cv.signal(&m);`
- e    `while (! progress_is_possible())`  
      `cv.signal(&m);`
- f    `if (progress_is_possible())`  
      `cv.signal(&m);`

5. [4 points] You write some multithreaded code. You follow the CS202 concurrency commandments, using one or more monitors.

**Is deadlock possible? If so, give a concise example, or refer to one. If not, say why not. Do not write more than two sentences.**

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## IV ls lab (15 points)

6. [15 points] The function `file_tree_count()`, listed below, starts at a directory (specified by `dirname`) and is supposed to count *all* files in the directory and, recursively, all of the files in that directory's subdirectories (and in their subdirectories, etc.). `file_tree_count()` uses system calls and logic similar to what you used in lab 2. However, it has three bugs, as indicated.

```
int file_tree_count(char* dirname)
{
    int count = 0;
    struct dirent* entry;
    struct stat st;
    char pathandname[512];

    DIR* dir = opendir(dirname);

    // **BUG 1**: What is the missing check between opendir and readdir?

    while ((entry = readdir(dir)) != NULL) {

        // **BUG 2**: A missing check. What kind of entries must we skip?

        snprintf(pathandname, sizeof(pathandname),
                 "%s/%s", dirname, entry->d_name);

        if (stat(pathandname, &st) == -1) {
            continue;
        }

        if (S_ISDIR(st.st_mode)) {
            // **BUG 3**: What is the bug in the following line?
            count += file_tree_count(entry->d_name);
        } else {
            count++;
        }
    }

    if (dir) closedir(dir);
    return count;
}
```

Below, say what the three errors are. You need not propose the correct version of the code.

BUG 1:

BUG 2:

BUG 3:

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## V EStore lab (30 points)

7. [30 points] In lab 3, you filled out an EStore class with an inventory driven by multiple threads executing handler functions. In this question, you will add support for two more EStore operations and the corresponding handler functions:

- EStore::removeStock(): this method takes an item denoted by `item_id` and `quantity` and removes that much from inventory. If there aren't enough of the item to remove, then wait until there are enough.
- EStore::swapStock(): this method atomically adds stock to one item with parameters (`add_id`, `add_quantity`) and removes stock from another item with parameters (`remove_id`, `remove_quantity`). As above, if there aren't enough of `remove_id` to remove, then wait until there are enough. When adding stock, wake up any threads waiting to remove that item.

Notes:

- The lab has a notion of validity that is not operative here: you can assume that all items are valid.
- You should treat EStore as a monitor, meaning use a single mutex that is provided in the EStore definition below.
- You do not have to worry about the interaction between the methods that you write here and the ones that you implemented for lab 3, as long as the two operations introduced in this question are properly synchronized with each other.

**Complete the (a) request structs, (b) handlers, (c) EStore members, and (d) EStore methods.**

```
// **** The following two structs belong in Request.h
struct RemoveStockReq
{
    EStore* store;
    // FILL IN BELOW

};

struct SwapStockReq
{
    EStore* store;
    // FILL IN BELOW

};
```

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```
// **** The following two handlers should be in RequestHandler.cpp
// * You need not print any handling messages.
// * Remember to delete your request.
void remove_stock_handler(void *args) {
    // FILL THIS IN
```

```
}
```

```
void swap_stock_handler(void *args) {
    // FILL THIS IN
```

```
}
```

```
// Possibly helpful definition, from EStore.h
```

```
class Item {
public:
    bool valid;    // assume always true
    int quantity;
    double price;
    double discount;

    Item();
    ~Item();
};
```

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```
// The following is a snippet of class EStore
class EStore {

    private:
        Item inventory[INVENTORY_SIZE];
        smutex_t mutex;
        // ADD MORE HERE

    public:
        // ...
        void removeStock(int item_id, int quantity);
        void swapStock(int add_id, int add_quantity,
                       int remove_id, int remove_quantity);
        // ...
};

void EStore::removeStock(int item_id, int quantity) {
    // FILL THIS IN

}

void EStore::swapStock(int add_id, int add_quantity, int remove_id, int remove_quantity) {
    // FILL THIS IN

}

}
```

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*Additional space if needed*

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## VI Scheduling (10 points)

**8. [10 points]** Consider the setup below, which follows an example from class. Time is divided into epochs. Jobs arrive at the very beginning of the epoch listed under “arrival epoch”; after they have been given the CPU for “burst length” epochs, they leave. Processes do no I/O.

<b>process</b>	<b>arrival epoch</b>	<b>burst length</b>
P1	0	5
P2	2	4
P3	3	1
P4	4	1

Assume that the scheduling algorithm is STCF (Shortest Time to Completion First, a preemptive algorithm). Of course, in general, STCF cannot be implemented because an algorithm cannot know in advance how long each process will run, but here we are given that information.

**Write down the process scheduled for each epoch beneath the epoch number (as we did in class):**

0 1 2 3 4 5 6 7 8 9 10

**What is the average turnaround time?**

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## VII Virtual memory and feedback (12 points)

9. [5 points] Assume an architecture with a 4-level page table, like the x86-64. But unlike the x86-64, here there are 44 bits used for addressing, broken down as follows:

[7 bits | 9 bits | 8 bits | 10 bits | 10 bits ]

The top 7 bits index into the L1 page table, the next 9 bits index into a L2 page table, and so forth. The bottom 10 bits determine the offset into the physical page. (Side note: this architecture is not a good idea, but that's not relevant to the question.)

**What is the maximum number of L2 page tables that can be allocated for a process on this architecture?**

10. [5 points] Describe a case where a memory reference on a machine with a hardware-managed TLB (like the x86-64) results in a TLB miss but not a page fault. Do not write more than two sentences.

11. [2 points] This is to gather feedback. Any answer, except a blank one, will get full credit.

**Please state the topic or topics in this class that have been least clear to you.**

**Please state the topic or topics in this class that have been most clear to you.**

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*Scratch space if needed*

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**Name:**

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End of Midterm

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