CS 111: Operating System Principles

Midterm Exam Spring ’21

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Fill in the Blank and Multiple Choice. (2 points each)

1. What is lower level than the operating system (or which does it abstract)?

   Hardware

2. What interface does a process use to interact with the kernel?

   System calls

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   System calls

3. What is something both monolithic kernels and microkernels need to do?

   Scheduling, basic IPC, or virtual memory

4. What is it called when the OS changes the current process to a new one?

   Context switch

5. Consider the following code snippet:

```
int main() {
  while (true) {
    fork();
  }
}
```

Assume that execution begins at main and fork never fails. How many processes are there at the end of the third iteration of the loop?

   8

6. What system call creates a new process?

   `fork`

7. What are signals NOT an example of
   a) concurrency
   b) inter-process communication
   c) interrupts
   d) virtualization

8. Which is NOT a metric to evaluate scheduling algorithms?
   a) waiting time
   b) throughput
   c) fairness
   d) frequency

9. What is the kind of scheduling called that has to be concerned with time constraints?

   Real-time scheduling

10. What do page tables map a virtual address to?

    Physical address

11. What hardware speeds up virtual address translation?

    Translation look-aside buffer

12. What is NOT an example of a trap?
    a) system call
    b) exception
    c) interrupt
    d) blocking

13. What is the optimal page replacement algorithm?
    a) replace the page that won't be used the longest
    b) replace a random page
    c) replace the oldest page
    d) replace the page least recently used

14. What CPU mode did your code execute in for Lab 0?

    Kernel mode

15. In Lab 0, what system call did you re-use to access internal kernel information?
    a) `read`
    b) `wait`
    c) `sbrk`
    d) `nice`

Short answers. (6 points each)

16. What are the benefits and pitfalls of dynamic libraries compared to static libraries?

17. Is a zombie orphan process possible? Explain.

18. What is priority inversion with respect to scheduling, and how would you mitigate it?

19. A CPU supports 39 bit virtual addresses. It has a 1 KiB page size, and each PTE (page table entry) is 8 bytes. How many levels of page tables would you need if you used hierarchical page tables? Justify your answer.

20. Describe how your solution in Lab 1 works when a user runs `./pipe ls wc`. Assume that the process id (pid) of the parent is 100, and `fork` creates children with pid 101 and 102. Also assume that the `pipe` system call returns file descriptor 3 in index 0 (the read end) and file descriptor 4 in index 1 (the write end). You can ignore errors.

Basic Scheduling. (20 points total)
For the following schedule questions use the following processes:

Process	Arrival Time	Burst Time
1	0	4
2	5	3
3	7	2
4	1	3
5	3	1

You'll be using these processes to create a schedule using round robin (with a quantum length of 2) and shortest remaining time first. Both algorithms use preemption. You'll need to create a schedule, then calculate the average waiting time and average response time for both algorithms.

Round Robin. (8 points)
For round robin (RR) scheduling with a quantum length of 2 time units please select which process is running during the specified time. If there are ties (e.g. one process is being re-queued while another one arrives) favor the arriving process.

What process is scheduled for round robin between time 0-1? **1**

What process is scheduled for round robin between time 1-2? **1**

What process is scheduled for round robin between time 2-3? **4**

What process is scheduled for round robin between time 3-4? **4**

What process is scheduled for round robin between time 4-5? **1**

What process is scheduled for round robin between time 5-6? **1**

What process is scheduled for round robin between time 6-7? **5**

What process is scheduled for round robin between time 7-8? **4**

What process is scheduled for round robin between time 8-9? **2**

What process is scheduled for round robin between time 9-10? **2**

What process is scheduled for round robin between time 10-11? **3**

What process is scheduled for round robin between time 11-12? **3**

What process is scheduled for round robin between time 12-13? **2**

Average Waiting Time. (1 point)
What is the average waiting time for the RR schedule you previously made? (Use one decimal place) **3.4**

Average Response Time. (1 point)
What is the average response time for the RR schedule you previously made? (Use one decimal place) **2**

STRF. (8 points)
For shortest remaining time first (SRTF) scheduling please select which process is running during the specified time. For ties (e.g. two processes have the same remaining time) favor the process that newly arrives. This will ensure your minimize average response time while not changing average waiting time.

What process is scheduled for round robin between time 0-1? **1**

What process is scheduled for round robin between time 1-2? **4**

What process is scheduled for round robin between time 2-3? **4**

What process is scheduled for round robin between time 3-4? **5**

What process is scheduled for round robin between time 4-5? **4**

What process is scheduled for round robin between time 5-6? **2**

What process is scheduled for round robin between time 6-7? **2**

What process is scheduled for round robin between time 7-8? **2**

What process is scheduled for round robin between time 8-9? **3**

What process is scheduled for round robin between time 9-10? **3**

What process is scheduled for round robin between time 10-11? **1**

What process is scheduled for round robin between time 11-12? **1**

What process is scheduled for round robin between time 12-13? **1**

Average Waiting Time. (1 point)
What is the average waiting time for the RR schedule you previously made? (Use one decimal place) **2.2**

Average Response Time. (1 point)
What is the average response time for the RR schedule you previously made? (Use one decimal place) **0.2**

Page Faults. (20 points total)
Assume the following accesses to physical page numbers:

1, 2, 3, 4, 5, 2, 3, 1, 4, 2

or in table format:

Access	1	2	3	4	5	6	7	8	9	10
Physical Page	1	2	3	4	5	2	3	1	4	2

Assume that all pages are initially on disk. For each access you'll have to answer which page gets evicted, and which page gets brought in. You have 4 physical pages in memory.

Unless otherwise stated, you'll be using the clock algorithm to replace pages. However, instead of doing nothing with the reference bit on a page hit, you'll set the reference bit to 1. This will allow the clock algorithm to approximate LRU.

Clock Algorithm - Evicted. (8 points)
For the modified clock algorithm, for each access, please state which page gets evicted (removed from physical memory) as part of the access.

For the modified clock algorithm on access 1, which page gets evicted? **None**

For the modified clock algorithm on access 2, which page gets evicted? **None**

For the modified clock algorithm on access 3, which page gets evicted? **None**

For the modified clock algorithm on access 4, which page gets evicted? **None**

For the modified clock algorithm on access 5, which page gets evicted? **1**

For the modified clock algorithm on access 6, which page gets evicted? **None**

For the modified clock algorithm on access 7, which page gets evicted? **None**

For the modified clock algorithm on access 8, which page gets evicted? **4**

For the modified clock algorithm on access 9, which page gets evicted? **2**

For the modified clock algorithm on access 10, which page gets evicted? **3**

Clock Algorithm - Swapped in. (8 points)
For the modified clock algorithm, for each access, please state which page gets swapped in (adds the page to physical memory) as part of the access.

For the modified clock algorithm on access 1, which page gets swapped in? **1**

For the modified clock algorithm on access 2, which page gets swapped in? **2**

For the modified clock algorithm on access 3, which page gets swapped in? **3**

For the modified clock algorithm on access 4, which page gets swapped in? **4**

For the modified clock algorithm on access 5, which page gets swapped in? **5**

For the modified clock algorithm on access 6, which page gets swapped in? **None**

For the modified clock algorithm on access 7, which page gets swapped in? **None**

For the modified clock algorithm on access 8, which page gets swapped in? **1**

For the modified clock algorithm on access 9, which page gets swapped in? **4**

For the modified clock algorithm on access 10, which page gets swapped in? **2**

Optimal. (4 points)
Instead of using the modified clock algorithm, use the optimal algorithm for the same page accesses. How many page faults are there for the optimal algorithm? **6**