**EC 440**
**Spring 2021**
**Final**
**05/06/21 8PM - 05/07/21 8PM**
**Time Limit: 120 Minutes**

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This exam contains 4 pages (including two cover pages) and 2 problems. Enter all requested information on the top of this page.

You are required to show your work on each problem on this exam. The following rules apply:

- **Organize your work**, in a reasonably neat and coherent way, in the space provided. Work scattered all over the page without a clear ordering will receive very little credit.
- **Mysterious or unsupported answers will not receive full credit**. A correct answer, unsupported by explanation, will receive no credit; an incorrect answer supported by substantially correct calculations and explanations might still receive partial credit.
- For multiple choice questions, put a checkmark beside every correct answer, **many** of the questions have **multiple** correct answers. Points will be deducted both for every incorrect answer checked and for every correct answer not checked.

| Problem | Points |
|---|---|
| 1 | 7 |
| 2 | 8 |
| Total: | 15 |

This is an open book test. You have two hours to finish it from time of download on gradescope. While you can take the exam at any two hour window in the twenty four hour exam period, instructors will be available between 8PM-10PM EDT on the 6th and between, 8AM-12PM and 6-8PM on the 7th, and as much as possible at other times through the exam period. If you have questions, and an instructor is available, they will be on Zoom at the regular course link:

https://bostonu.zoom.us/j/91404923667?pwd=YmJ4T0tiakMvYmtBU2hieTNocUVyQT09

**What you're allowed to do:** Since you are allowed to access external materials for this exam, we are not requiring a lockdown browser. You may Google for publicly available information if you wish, even if you only have one device available to you; however be aware of the time limit for the exam. In addition we are allowing you to access all questions through the entire exam; you can decide in what order you wish to complete questions, and can double-check and revise your work before submission.

**What you're not allowed to do:** You are expected to adhere to Boston University's academic code. Although we are allowing you to access external materials and information during the exam, you are required to perform all the work required to solve the exam problems, and to do that work during the time allotted.

**Honor code**

By taking this exam, I agree that:

1. I am the person who is supposed to be taking this exam and no one is helping me (physically or electronically)
2. I will not copy the exam questions in part or whole by any means
3. I will refrain from discussing this exam with anyone other than my professor until after May 8, 2021
4. I will adhere to the academic code outlined in the Student Handbook

1. Multiple choice questions. Put a checkmark beside every correct answer, **many** of the questions have **multiple** correct answers. Points will be deducted both for every incorrect answer checked and for every correct answer not checked.

   (a) (3 points) Why do we fork before calling exec to launch a program from a shell?

   - ⊗ Without a fork, it would be impossible to run a background process.
   - ⊗ Exec replaces the current process image with a new process image.
   - ◯ The program runs faster because it uses more forks.

   (b) (4 points) Which of the following are things that CoW helps with?

   - ⊗ Ensures that one user of shared data will not impact another user's data consistency when writing to the shared space.
   - ◯ Ensures all data never needs to be copied.
   - ⊗ Reduces memory consumption when sharing unmodified data.
   - ◯ Automatically encrypts private data.

2. Consider the following code that implements part of a shell:

```
// ... argv[] is an array containing command args.
//     E.g., {"ls", "-al", NULL}
if ((pid = fork()) == 0) {
    execvp(argv[0], argv);
} else {
}
// Continues processing the next part of the shell input...
```

wait on the pid here

(a) (4 points) You attempt to test the shell, and you find that the shell immediately prints another prompt after you enter your first command. The expected behavior is that the next prompt will not print until after the first command finishes executing. Annotate the above code to indicate what would fix the problem.

(b) (4 points) You fixed the bug, and moved on to test whether the shell supports background processes. Everything seems to work okay at first, since the shell does not proceed while foreground processes are running and the shell does proceed even while background processes are in progress. However, you noticed that after the background processes finish, their process IDs are still in use. Why is this happening?

The leftover process IDs are from zombie processes. They need to be reaped by waiting on terminated processes in a sigchld handler.