This exam is a closed book, closed notes, closed laptops and smartphones, etc. exam
- All that you can use is either a pen or pencil
- The last few pages provide formula, which you may be helpful
- Do not spend too much time on any one question.

Name (Print) ________________________________________________________________

Honor Code statement : I pledge that this submission is solely my work. I pledge that I have not provided help to anyone. I pledge that I have not received help from anyone.

Signature ___________________________________________________________________

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I. True/False. Circle either True or False. No partial credit.

1. True / False  A data hazard arises when there are not enough functional units of the same step of a pipeline to permit multi-threading.

2. True / False  When a semaphores is created, it must be initialized to 0 (zero).

3. True / False  Every loop in a program should be parallelized if there are idle CPUs waiting

4. True / False  In the context of concurrent programs, partial correctness is achieved when every loop and procedure call terminates

5. True / False  Two processes are independent when the write set of each is disjoint from the read and write sets of the other.
II. Multiple Choice. Circle the ONE letter to specify the BEST answer choice from among those listed. No partial credit.

6. If the below for loop were parallelized, how many different ways could the parallel version of the program print out the values of i? Assume `print(i)` is an atomic action.

   ```
   for (i=0; i<3; i++) {
       print(i);
   }
   ```

   A. 1  
   B. 2  
   C. 4  
   D. 6  
   E. 12  
   F. None of the above

7. For a pipeline with depth 4, with stage 1 latency of 2ns, stage 2 latency of 2ns, stage 3 latency of 4ns and stage 4 latency of 2ns, which of the following statements is true.

   A. If the pipeline is empty, upon processing a single instruction, the observed pipeline latency will be 12ns for that one instruction.  
   B. Assuming no stalls, after a large number of instructions have been executed, the observed pipeline throughput will be 2 instructions every 1 ns  
   C. If the pipeline is empty, and 2 instructions are processed, one after the other, then the second instruction’s latency for the entire pipeline will be 12 ns  
   D. None of the above
III. Semaphores. Partial credit given.

8. The pseudocode below contains three functions, calcA() and calcB(), each with 2 instructions, and main(). All instructions inside calcA and calcB are atomic. Assume that a Semaphore class is available, which has a constructor Semaphore(int semaphoreValue), and functions increment() and decrement(). Variables x and y are global variables (ie, shared among all functions) saved in shared memory. Declare and use semaphores wherever needed, so that when the main method runs to completion, the output of the program is:

Values of x and y are 7 and 12

You can ONLY declare and use semaphores. You cannot update existing variables’ values, insert new code other than semaphores, etc.

```plaintext
function calcA(){
    x = x + 1;
    y = 12;
}
function calcB(){
    y = x + 1;
    y = y + 1;
}
main(){
    x = 6; y = 7;
    co
    calcA();
    calcB();
    oc
    print(“Values of x and y are “, x, “ and “, y);
}
```
IV. Short Answer. Provide a concise answer to each question. Partial credit.

9. Are either of the arms in the below concurrent program at-most-once? Why or why not. Explain.

```
int x = 44, y=712;
co x = x + 1; // y++; oc
```

Your answer:

______________________________________________________________

______________________________________________________________

______________________________________________________________

10. Assume a 5 step pipeline with the following stage latencies

   Stage_1 5ns
   Stage_2 6ns
   Stage_3 8ns
   Stage_4 3ns
   Stage_5 4ns

Under these conditions, what will be the pipeline’s throughput when the 12,435\textsuperscript{th} of 20,000 instructions is executing, and what will be the pipeline’s latency, also for instruction 12,435? Do not assume any stalls other than those that might be imposed by the stage latencies listed above.

Pipeline throughput:

______________________________________________________________

Pipeline latency:

______________________________________________________________

11. What cache reuse ratio is needed so that a program that uses cache is 2 times better (performance gain) than a program that does not use cache? Assume cache access time of 3ns and memory access time of 24ns.

Your Answer:

______________________________________________________________
12. Assume the below code statements $S_1$ and $S_2$, and that $x$ and $y$ are both initially 8. Both $x$ and $y$ are shared variables.

$S_1$: $x = x + 1$
$S_2$: $y = y - x$

Under these conditions what are the possible final values of $x$ and $y$ when program P1, below, executes to completion?

P1 : co <S1;> // <S2;> oc

Possible value(s) of $x$: ________________________________
Possible value(s) of $y$: ________________________________

13. Define the term concurrent

Your Answer: _______________________________________

V. Multiple Answers. Select ALL letters that are correct answers for the question. One, two or more, or even all choices may constitute a full correct answer. Partial credit is given.

14. Which of the following is/are true about the syntax and functionality of the sample await statement in the below box?

< await (p > 0) s = s + 10 >

A. $s = s + 10$ is the delay condition
B. The < > brackets specify an atomic action
C. $s = s + 10$ begins executing when $p = 0$
D. It is possible that this await statement implements the behavior of an infinite loop
E. $p > 0$ is guaranteed to be false when execution of $s = s + 10$ ends
VI. Extra credit. Partial credit not given.

Two extra credit questions will appear on the real exam.

VII. Formula

Cache/Main memory gain

\[ G(\tau, \beta) = \frac{\tau}{\beta + \tau(1-\beta)} \]

\[ T_c = \frac{T_m}{\tau} \]