Write your test number on all pages because the pages will be separated for grading.
No books, no notes, but calculators are allowed. If you need to make an assumption to solve a problem, state the assumption.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Score</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>/10</td>
</tr>
<tr>
<td>2</td>
<td>/5</td>
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<td>3</td>
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<td>4</td>
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<td>5</td>
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<tr>
<td>6</td>
<td>/30</td>
</tr>
<tr>
<td>7</td>
<td>/25</td>
</tr>
<tr>
<td>Total</td>
<td>/100</td>
</tr>
</tbody>
</table>
1. 10 pts. For each of the following, specify whether it results in an Interrupt (I), Exception (trap) (E), or Neither (N):

   (a) Test and Set instruction
   (b) Disk read completed
   (c) Attempt to write to read-only memory
   (d) System call (fork, for example)
   (e) Call to library routine (strcpy, for example)

2. 5 pts. The Banker’s algorithm deals with deadlock via:

   (a) Deadlock Avoidance
   (b) Deadlock Prevention
   (c) Deadlock Detection and Recovery

3. 10 pts. If there are \( n \) separate process, each with its own address space and a page frame size of \( p \) bytes, what is the expected amount of space lost due to internal fragmentation?

4. 10 pts. Give a short description of the terms race condition and deadlock.
5. 10 pts. If the cost of accessing the TLB is 20 ns. and of accessing main memory is 200 ns., what is the minimum TLB hit rate (percentage of time a lookup is found in the TLB) necessary in order to achieve an effective memory access time of 260 ns? Assume a single-level page table and a serial algorithm.

6. 30 pts. The following table lists the arrival time, execution time, and priority (higher number means greater priority) of 5 jobs.

<table>
<thead>
<tr>
<th>Job</th>
<th>Arrival time</th>
<th>Execution time</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
<td>40</td>
<td>5</td>
</tr>
<tr>
<td>C</td>
<td>30</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>D</td>
<td>60</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>100</td>
<td>60</td>
<td>2</td>
</tr>
</tbody>
</table>

Give the start time (the time the job is first scheduled; note that a job may have to wait when it arrives), the end time, the wait time, and the turnaround time of each of the jobs using each of the following scheduling algorithms.
(a) Shortest Job First (without preemption)

(b) Priority (without preemption)

(c) Round-Robin with a quantum of 20
7. 25 pts. We have two processes which each repeatedly execute two sections of code, and then increment a shared variable:

\[
\text{shared Integer numIterations} = 0;
\]

Process A

\[
\text{loop begin}
\]

A1;

A2;

numIterations++;  

\[
\text{loop end;}
\]

Process B

\[
\text{loop begin}
\]

B1;

B2;

numIterations++;  

\[
\text{loop end;}
\]

We want to satisfy the following constraints:

(a) Statement A2 in the \(i\)th iteration of A’s loop cannot execute until statement B1 executes in the \(i\)th iteration of B’s loop

(b) Statement B2 in the \(i\)th iteration of B’s loop cannot execute until statement A1 executes in the \(i\)th iteration of A’s loop

(c) numIterations must always maintain the number of loops process A has completed plus the number of loops process B has completed

Add to the existing code to satisfy the given constraints, but without adding additional constraints (for example, it shouldn’t matter whether A1 or B1 executes first).

You may declare additional shared or local variables of type Integer, Boolean, or Semaphore, but make sure to give them initial values.