These are not the only answers that are acceptable, but these answers come from the notes or lectures.

1. (a) 2 marks A buffer smoothes out small, temporary differences in speed between adding and removing threads so they seldom block. The speed of the adding and removing threads must be virtually equal or the buffer is always full or empty.

(b) 2 marks Synchronization is required to prevent adding/removing when the buffer is full/empty. Mutual exclusion is required to atomically add/remove elements at each end of the buffer.

(c) 1 mark Baton passing conceptually passes the lock when unblocking to achieve barging prevention.

(d) 2 marks
   - both readers enter $\implies$ 2:00 reader reads data that is stale; should read 1:30 write
   - writer enters and overwrites 12:30 data (never seen) $\implies$ 1:00 reader reads data that is too fresh (i.e., missed reading 12:30 data)

(e) 2 marks No, FCFS (FIFO)

(f) 2 marks The V on the read bench (semaphore) is remembered by the semaphore counter, so when the reader finally restarts and P's on the read bench, it does not block.
2. (a) **2 marks** A race condition occurs when there is missing synchronization or mutual exclusion.
   It is hard to locate because the program runs but problems do not occur immediately because of non-determinism.

(b) **10 marks** 2 each
   i. 4, the quadrants over which the cars drive
   ii. 4, right hand turns
   iii. 2, driving through the intersection
   iv. 3, making a left-hand turn.
   v. 4, the cars move into their quadrant simultaneously

(c) i. **1 mark** mutual exclusion deadlock
   ii. **3 marks**

```
L1.P() 1 L1.P()  
R1  
L2.P() 1 L2.P()  
R1 & R2 1 R2 // access resource 
R2 & R1 // access resource
```

iii. **2 marks** Resource utilization is reduced because task2 holds R1 longer than necessary.

(d) i. **4 marks**

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>11 Total Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Needed</td>
<td>2</td>
<td>7</td>
<td>5</td>
<td>8</td>
<td>-11 Used</td>
</tr>
<tr>
<td>Acquired</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>7</td>
<td>0 Available for allocation</td>
</tr>
<tr>
<td>Needed Max</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

```
P1  0
   2
P4  1
   9
```

```
P2  4  P3  6
  11 11
P3  4  P2  4
   9 11
```

The state is safe as there are 2 sequences of execution that are safe.

ii. **3 marks**

```
P1  0
   2
P4  1
   9
```

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</table>

```
P1  0
   2
```

The state is NOT safe as there are insufficient resources for any process to execute so no sequence of execution is possible after this point.
3. (a) **11 marks** 3(a)v is 2 marks
   i. e
   ii. a and b called X, c called Y
   iii. d on A; g, h on B
   iv. mutex queues are auxiliary queues to allow O(1) access for the accept statement
   v. tasks f accepts a mutex queue with e at the front, and e does an accept
tasks e and f were on a condition variable and both were signalled
   vi. signalling task
   vii. signalled task or a calling task
   viii. d (or signalled task)
   ix. signalling task, and tasks g h are moved to the A/S stack
   x. a enters, and the accepting task, e and f are on A/S stack

(b) **2 marks** Yes, when the accepted call raises an exception, the acceptor receives the implicit
RendezvousFailure from the caller.

(c) **2 marks** µC++ monitors prevent barging by giving the acceptor/signaller (A/S) stack highest
priority before looking at the calling queue (C < W < S).

(d) **3 marks** advantage: no heap allocation to create a node and no data copy to the node
disadvantage: link fields occupy space in the data and may be used infrequently or not at all

4. (a) **1 mark** Without a stack, a thread has no where to start execution.

(b) **2 marks**

   \[ \text{Accept}( m_1, m_2 ) \Rightarrow \text{Accept}( m_1 ) \text{ or Accept}( m_2 ) \text{ or } \]

(c) **3 marks**

   \[ \text{Task } T \{
   \text{public:}
   1 \text{ void start() } \}
   1 \text{ void main() } \{
   1 \text{ Accept( start ); } \quad \text{// 1st line}
   \text{...}
   \]  

(d) **1 mark** monitor

(e) **1 mark** The task’s thread needs to do work or why create it, and the concurrency is inhibited for
the caller.

(f) **1 mark** The administrator never makes a blocking call (calls out).

(g) **2 marks** An asynchronous call returning a result needs a mechanism (future) to match a com-
pleted result with the calling client.
5. (a) **1 mark** Caching transparently hides the latency of accessing main memory.
(b) **1 mark** Cache coherence ensures a shared value is uniformly updated across the cache giving a consistent view of values.
(c) **2 marks**
   \[
   \text{Insert} = \text{true}; \ // W \\
   \text{Data} = i; \ // W
   \]
   Allows reading of stale data.
(d) **2 marks**
   i. Declaration qualifier **volatile** prevents variables from being hidden in registers.
   ii. A shared flag is loaded into a register and checked there, hence it is impossible to see the flag change.
(e) **2 marks** A counter is added to count pushes, which the CASD saves atomically. The counter ensures the second push of A in ABA has a different count value from the first push.
(f) **2 marks** Threads are declared but a join member is used rather than deallocation for termination synchronization.
6. (a) 8 marks

L2:
1  if ( voters < group ) _Throw Quorum();

L3:
1  try {
1    for ( ;; ) {
1      _Accept( done ) {
1      if ( voters < group ) break;
1      } // for
1    } catch(uMutexFailure::RendezvousFailure &) {}  
1  _Throw Quorum();

(b) 6 marks

L1:
1   uCondition bench;

L2:
1  if ( voters < group ) _Throw Quorum();

L3:
1    bench.wait();

L5:
1    bench.signal();
1  _Throw Quorum();

L6:
1  if ( voters < group ) bench.signal();

(c) 6 marks

L1:
1   AUTOMATIC_SIGNAL;

L2:
1  if ( voters < group ) _Throw Quorum();

L3:
1    WAITUNTIL( numVotes == 0, );

L5:
1    RETURN(talliedResult);

L6:
1  if ( voters < group ) numVotes = 0;
1   RETURN();
7. 29 marks

```c
void flush( bool kind ) {
    for ( int i = 0; i < votes.size(); i += 1 ) { // flush
        votes[i]->ftour.exception( kind ? new Quorum : new Closed );
        delete votes[i];
    } // for
    votes.clear();
}

void main() {
    for ( ;; ) {
        _Accept( ~TallyVotes ) { // shutdown ?
            break;
        } or _Accept( done ) { // voter leaves
            voters -= 1;
            if ( voters < group && votes.size() ) { // failure ?
                flush( true ); // Quorum failure
            }
        } or _Accept( vote ) { // voter
        } or _Accept( tour ) { // guide
        }

        if ( ! wguides.empty() && votes.size() >= group ) { // guide and group ?
            for ( int i = 0; i < group; i += 1 ) { // compute rank
                add( votes[i]->ballot );
            }
            gtour = tally(); // compute vote
            for ( int i = 0; i < group; i += 1 ) { // put vote in futures
                votes[i]->ftour.delivery( gtour );
                delete votes[i];
            }
            votes.erase( votes.begin(), votes.begin() + group ); // shorten
            wguides.signalBlock(); // unblock guide
            reset(); // reset vote counters
        }
    }
    // Shut down and tell the tourists/guides to go home
    closed = true;
    for ( int i = 0; i < guides; i += 1 ) {
        if ( wguides.empty() ) _Accept( tour );
        wguides.signalBlock();
    }
    flush( false ); // Closed failure
}
```