First read the entire examination. There are 6 exercises in total. Grades are included between parentheses at all parts and sum up to 11 points. Good luck!

1. The so-called hyperbolic bound for a set of \( n \) tasks is given by

\[ \text{HB}(n) = \prod_{1 \leq i \leq n} (U_i + 1) \leq 2. \]

(a) (0.5) What does this bound represent?
Answer A sufficient schedulability test for rate monotonic scheduling (RMS).

(b) (0.5) Give at least three assumptions that need to hold to use this bound.
Answer See assumptions for RMS in book.

(c) (1.0) Give an example of a task set \( T \) that satisfies this bound, and has the additional property that an increase of the computation time of any task of \( T \) will make \( T \) unschedulable.
Answer Let \( T \) consist of 2 tasks, with \( C_1 = 2 \), \( T_1 = 5 \), \( C_2 = 3 \), and \( T_2 = 7 \). These values for the tasks satisfy the conditions for a minimal total utilization, i.e. \( T_1 < T_2 < 2T_1 \), \( C_1 = T_2 - T_1 \), and \( C_2 = 2T_1 - T_2 \); see book p. 89. Now \( U_1 = \frac{2}{5} \), \( U_2 = \frac{2}{7} \), \( \prod_{1 \leq i \leq 2} (U_i + 1) = 2 \), and the hyperbolic bound is therefore satisfied. Increasing either \( C_1 \) or \( C_2 \) will make the task set unschedulable, as becomes immediately clear when drawing a timeline with a simultaneous release at time zero.

This exercise has been taken from sheet 30 of ‘RTA.B5-Analyse-1’.

2. (2.0) Using a sporadic server with capacity \( C_S = 2 \) and period \( T_S = 5 \), schedule the following tasks, (i.e. draw a timeline for the tasks and the capacity of the server as a function of time):

<table>
<thead>
<tr>
<th>periodic tasks</th>
<th>aperiodic tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>( C )</td>
<td>( T )</td>
</tr>
<tr>
<td>( \tau_1 )</td>
<td>1</td>
</tr>
<tr>
<td>( \tau_2 )</td>
<td>2</td>
</tr>
<tr>
<td>( J_3 )</td>
<td>10</td>
</tr>
</tbody>
</table>

Assume rate monotonic scheduling, and a simultaneous release of the periodic tasks at time zero.
Answer See book Exercise 5.6.
3. Consider the periodic tasks and the sporadic server given in the previous exercise, and assume rate monotonic scheduling.

(a) (0.5) Determine whether or not the periodic tasks and the sporadic server are schedulable.

Answer From a timeline with a simultaneous release at time zero and a complete utilization of the sporadic server, we see that \( \tau_2 \) misses its deadline. Hence, the periodic tasks and the sporadic server are not schedulable under worst-case conditions.

(b) (0.5) Describe how to determine the minimal period \( T_{\min}^{\tau_2} \) for task \( \tau_2 \) for which the periodic tasks and the sporadic server are schedulable under worst-case conditions. Also determine the value of \( T_{\min}^{\tau_2} \).

Answer Given the timeline constructed for item (a), we immediately see that extending the period to 8 will make \( \tau_2 \) schedulable, hence \( T_{\min}^{\tau_2} = 8 \).

4. Consider three periodic tasks \( \tau_1 \), \( \tau_2 \), and \( \tau_3 \) (having decreasing priority), which share three resources, \( A \), \( B \), and \( C \). Compute the maximum blocking time \( B_i \) for each task for the following two protocols, knowing that the longest duration \( D_i(R) \) for a task \( \tau_i \) on resource \( R \) is given by the following table (there are no nested critical sections):

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \tau_1 )</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>( \tau_2 )</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>( \tau_3 )</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

(a) (1.5) Priority Inheritance Protocol.

Answer See book Exercise 7.2.

(b) (1.5) Priority Ceiling Protocol.

Answer See book Exercise 7.3.

5. One of the motivations for resource reservation is to prevent temporal interference between applications.

(a) (0.5) Explain the notion of temporal interference.

(b) (1.0) Explain the concept of resource reservation, including the four elements on which it is based.

(c) (0.5) Explain how temporal interference between applications can be prevented by resource reservation.

Answers See slides of ‘RTA.D8-Resource reservation’.

6. Consider two different activation paradigms, time triggered (TT) and event triggered (ET).

(a) (0.5) Explain both paradigms in your own words.

(b) (0.5) Give two relative merits of TT compared to ET.

Answers See slides of ‘TT-ET+offline’.