Problem 1 [10 pts]

Compare and contrast the following processors. How do they differ? Among other things, pay particular attention to the execution pipeline, (super)scaling, ISA, memory, and power. What kinds of embedded applications/systems would be beneficial on each, and why (what architectural elements - e.g. VLIW, Harvard architecture, GPU stream instructions, etc.)

i) Cortex M3
ii) Snapdragon 845
iii) TI C67x

Answers may vary.

Problem 2 [10 pts]

As discussed in the lecture, scratchpad memories (SPM) provide low-latency, low-power access.

a. Why not design a system to only make use of scratchpad memory?
b. Find SoCs that use SPM and explain why using SPM is beneficial for these applications/SoCs. Answers may vary.

We also talked about Resistive random-access memory (ReRAM) as an emerging technology.

c. List 3 major advantages of ReRAM over traditional SRAM and/or DRAM for embedded systems.

d. What types of applications would it not be appropriate for?

e. Why/how using ReRAM can accelerate the applications?

Answers may vary.
Problem 3 [10 pts]
Assume that a sensor output an analog signal of frequency 80Hz. You are sampling the input analog signal with a 5-bit ADC converter with resolution 0.5V.

1. What is the maximum quantization error?
   Either 0.5 or 0.25 based on your assumptions

2. What is the maximum voltage that can be sampled with zero quantization error? Assume that the minimum voltage is 0V.
   Maximum quantization error= 0.5 V
   
   - 5bit → 2^5-1 steps
   Quantization error = (Vmax-Vmin)/steps → 0.5 = (Vmax-0)/31 → Vmax = 15.5V
   Or 0.25 = Vmax/31/2 → Vmax = 15.5

3. What will be the digital output of 4.3V?
   4.3 is rounded to 4.5 and 4.5 is equal to 01001

4. What could be the input voltage if the output is 11001?
   Either (12,12.5] or (12.25,12.75]

5. What is the minimum frequency at which you should sample the input signal to avoid aliasing?
   80 Hz*2 = 160 Hz
Problem 4 [10 pts]

Consider that a single processor runs 3 periodic tasks which are defined in the table below.

<table>
<thead>
<tr>
<th>Task</th>
<th>Worst case execution time (WCET)</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>x</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>12</td>
</tr>
</tbody>
</table>

a) Find the minimum period of task B, x, which fulfills the rate-monotonic inequality, where x is an integer. Show all work to get the full credit.

*Hint:* $2^{1/2} \approx 1.414; \ 2^{1/3} \approx 1.260; \ 2^{1/4} \approx 1.189$

$x = 8$

\[
\frac{1}{4} + \frac{2}{x} + \frac{3}{12} \leq 3 \times (2^{1/3} - 1) = 3 \times 0.26 = 0.78 \\
\frac{2}{x} \leq 0.78 - 0.5 = 0.28 \\
7.14 \leq x
\]

b) Using x found in part a, fill tasks scheduled by RM in the table below. Assume the following:
   - All tasks arrive at the time $t = 0$.
   - If multiple tasks have the same priority, use alphabetic order to break the tie
     e.g., if task A and task B have the same priority, run task A first

\[
\begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|}
\hline
\text{Time} & 0 & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 \\
\hline
\hline
\end{array}
\]

\[
\begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|}
\hline
\text{Time} & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 20 & 21 & 22 & 23 \\
\hline
\end{array}
\]
c) What if the period of the task C is $x-2$, is it still schedulable using RM?
Assume the following:
- All tasks arrive at the time $t = 0$.
- If multiple tasks have the same priority, use alphabetic order to break the tie
  e.g., if task A and task B have the same priority, run task A first

$X-2=6$

<table>
<thead>
<tr>
<th>Time</th>
<th>0</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>10</th>
<th>11</th>
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<tbody>
<tr>
<td>Task</td>
<td>A</td>
<td>C</td>
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</table>

It is not schedulable at 8

<table>
<thead>
<tr>
<th>Time</th>
<th>12</th>
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<th>15</th>
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<td>Task</td>
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d) Using $x$ found in part a (with the same assumption as part a), fill tasks scheduled by EDF in the table below

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<tr>
<th>Time</th>
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<tr>
<td>Task</td>
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<td>C</td>
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<tbody>
<tr>
<td>Task</td>
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</table>
Problem 5 [10 pts]
a) Given the three tasks, illustrate the Lamport’s logical times on each dot

b) For the same tasks, illustrate the timestamps using vector time on each dot