Problem 1 [10 pts]
Answer following questions by analyzing the IoT device: *Amazon Echo Dot*. You should do some research beyond the class material.

a) List HW and SW components of the device, and briefly discuss how those components are exploited in the embedded systems

*Answers vary*

b) List three major resource constraints that exist or might be encountered in the device design

*Answers vary*

c) Discuss the needs of HW/SW codesign to address each of the constraints you described in b)

*Answers vary*
Problem 2 [10 pts]
Examine the following Esterel code snippet:

```
await A emit M;
present B then
  emit N
end present;
pause;
abort
  loop
    present C then emit O else emit P end;
  pause;
end loop
when D;
emit Q;
```

a) Given the following timeline and input sequence, list all expected outputs at each time point.
*Hint: You may find this extensive reference paper useful:*
https://www.researchgate.net/publication/242374294_The_Esterel_v5_Language_Primer_Version_v5_91

```
input
  A
  B
  C
  C
  C
  C
  D
output
  M
  N
  P
  P
  P
  O
  O
  P
  O
  Q
```

b) Draw the FSM (finite state machine) that accurately presents functionality of the Esterel code.
*Hint: be mindful of the differences between instantaneous statements and delayed statements.*
Problem 3 [15 pts]
Consider the following Petri Net specification with P places, T transitions, A flows and W arc weights:

\[ P = \{P1, P2, P3, P4, P5, P6\} \]
\[ T = \{t1, t2, t3, t4, t5, t6\} \]
\[ A = \{(P1 \ t1), (P1 \ t3), (P1 \ t4), (P2 \ t2), (P3 \ t2), (P4 \ t4), (P4 \ t5), (P6 \ t6),
(t1 \ P2), (t1 \ P3), (t2 \ P1), (t3 \ P4), (t4 \ P5), (t5 \ P6), (t6 \ P6)\} \]
\[ W(P1, t3) = 2, W(P6, t6) = 2, W(t5, P6) = 2, W(t6, P6) = 2 \]
… all other arc weights are 1.

Given initial marking \( M_0 = [1, 1, 1, 0, 0, 0] \) for \{P1, P2, P3, P4, P5, P6\}:

a) Draw the Petri Net
b) Draw the reachability graph

- What is the liveness of transition t1?
  L3 live (can fire infinitely for t1, t2, t1, t2, ...)
- What is the liveness of transition t3?
  L1 live (can fire only once)
- What is the liveness of transition t4?
  L0 live / dead
- Is the net pure?
  No (A self-loop exists for t6)
- Is the net conservative?
  No (The number of total tokens may increase and decrease)

---

c) Answer the following questions in one line:
  - What is the liveness of transition t1?
    L3 live (can fire infinitely for t1, t2, t1, t2, ...)
  - What is the liveness of transition t3?
    L1 live (can fire only once)
  - What is the liveness of transition t4?
    L0 live / dead
  - Is the net pure?
    No (A self-loop exists for t6)
  - Is the net conservative?
    No (The number of total tokens may increase and decrease)
Problem 4 [15 pts]
Given the following SDF graph:

a) Write the incidence matrix. Use columns to represent the nodes, and rows to represent each edge.

\[
\begin{bmatrix}
A & B & C & D \\
8 & -3 & 0 & 0 \\
b & 0 & 3 & -8 & 0 \\
c & -5 & 0 & 5 & 0 \\
d & -8 & 0 & 0 & 4 \\
e & 0 & -3 & 0 & 4 \\
f & 0 & 0 & -10 & 5 \\
\end{bmatrix}
\]

b) What is the rank of the matrix? Also explain briefly how we can infer the existence of a periodic admissible sequential schedule (PASS) based on this rank?

Rank: 3
If \(\text{rank} = \#\text{nodes} - 1\), PASS schedule is possible
c) Find a PASS schedule given the following order of tasks \((A \rightarrow B \rightarrow C \rightarrow D)\) (Hint: you need to solve the linear system of equation for the incidence matrix. Show sufficient steps to find the schedule.)

\[
\begin{align*}
\text{AAABBBB BBBBCCCC DDDD} \\
3*A, 8*B, 3*C, 6*D
\end{align*}
\]

d) Find the initial number of elements in each edge buffer for the PASS schedule found in c) (Hint: execute one cycle of your PASS schedule manually to find the number of initial elements necessary in each buffer.)

\[
[ 0 \ 0 \ 15 \ 24 \ 24 \ 30]
\]

e) Find the minimum size required of each edge buffer.

\[
[24 \ 24 \ 15 \ 24 \ 24 \ 30]
\]
Problem 5 [15 pts]
Consider this description of an embedded system:

We are designing a car monitoring and emergency detection system using sensors and actuators to safely operate a vehicle. The user will be able to turn on and off the ignition, and the system will monitor several sensors and actuate warnings/alarms for emergency scenarios.

The follows are the description of the system:

1) Before pushing the ignition button, the system is in the “INITIAL” state.

2) After pushing the ignition button, the system receives the input message “IGNITION”, and sends the output message, “MOTOR_ON”, to start the motor, and goes to a “DRIVING” state.

3) If the ignition button is pushed (i.e., “IGNITION”) in the “DRIVING” state again, the system sends “MOTOR_OFF”, and reverts back to the “INITIAL” state.

4) When in either the “INITIAL” or “DRIVING” state, it may identify any anticipated emergency situations. Once the system receives the input message, “CAUTION”, it goes to the “WARNING” state.

5) In the “WARNING” state, a proximity sensor can detect the distances to surroundings. If the corresponding “PROX” message occurs, the system outputs the “LED_YLW” message, and goes into the “ALARM” state.

6) If high temperature is detected in either the “WARNING” or “ALARM” state, the system receives the “FIRE” message, and goes into the “STOP” state.

7) Before going to the “STOP” state, it should change the color of the LED with “LED_RED”.

8) If “CLEAR” message is in either the “WARNING” or “ALARM” states, the system turns off the LED with “LED_OFF”, and should go back to the original state, i.e., one of “INITIAL” or “DRIVING”. For example, if the vehicle was in “DRIVING”, it should be still in the same state.

9) When in the “STOP” state, it cannot change its states anymore.

In this system, there are 5 states and 10 input/output messages to operate sensors/actuators as follows:

State: “INITIAL”, “DRIVING”, “WARNING”, “ALARM”, “STOP”


Use the given state and message names to answer the questions below.
a) Draw a StateChart that accurately represents the functionality of the system. Use two superstates where appropriate to make your state diagram more readable. Each of all 5 states has to belong to one of the superstates.

- Any of equivalent representations will be okay.
- But, it has to specify the history state in a correct format.

b) Draw the equivalent SDL representation. Assume here that if the “CLEAR” message is received in the “WARNING” and “ALARM” states, the system outputs “MOTOR_OFF” and “LED_OFF”, and always reverts back to the “INITIAL” state (i.e., instead of 8) above.) Apart from this modification, your answer must be consistent with the StateChart shown in part a).
Problem 6 [10 pts]
Given the following StateChart, draw the equivalent Finite State Machine (FSM):

[Diagram of StateChart and equivalent FSM]