1.0 Problem 1 (75%)

Congratulations. You have been hired as a consultant to the startup company Smart-Window. The purpose of the company is to make intelligent windows. Windows that know when to open and close themselves. Windows that know what is going on and act accordingly.

Unfortunately, while you thought you were going to be doing intelligent user interfaces, it turns out that the company is actually into physical (glass) windows, not computer display windows. However, you have a contract and have to do the work. Luckily, you took CSCI1600 at Brown.

To build their product they have gathered a variety of technologies. They have sensors indicating when it is starting to rain (moisture sensors); they have indoor and outdoor thermometers; they have a control panel with a small number of switches and a LCD display; they have a motor with will automatically open or close the window (or stop after a certain amount). They have also been talking about placing shades in the window with automatic controls and having other external sensors that measure things such as wind direction and speed. The reason they hired you, however, is that they have no idea how to put all this together into a working system.

Their initial product, what they want you to do first, is a smart skylight. The skylight is supposed to automatically open if doing so will make the room more comfortable (i.e. if the room is too cold and it is warmer outside or if the room is too warm and it is cooler outside). The skylight is supposed to close automatically if it starts to rain. (It is a skylight.) There should also be manual overrides (so you can open the skylight when you burn something in the kitchen, say.)

1. Show how you might create an embedded system using the above hardware to control the skylight. Explain what types of components you would use to interface between the CPU and the external devices. Show the control panel and explain the function of each of the switches. Draw a high-level diagram showing the relationships between the components.

2. Using statecharts or another form of finite automata, show how the system would operate. Include an English explanation of what is going on so that the contractors who formed the company can understand it.

3. Using a Petri net, create a diagram to show all the interactions that might happen relating to opening/closing the skylight and rain. Could you use the petri net to show that the skylight will always be closed if it rains? Explain how this would be done. How about showing that this will happen unless the user explicitly overrides the automatic settings (presuming this is allowed by your design)?
4. Create a finite model of the system using properties related to open/close, rain, and whatever else is relevant to the situation in 3). State the property that if it rains then the window will be closed until the rain stops using temporal logic. Describe how you might prove this using the finite model.

Recall the temporal path operators:

- \( X f \): f will be true in the next step of the path
- \( F f \): f will be true eventually on the path (in the future)
- \( G f \): f will always be true on the path
- \( f U g \): f holds up to a state where g holds on the path (until)
- \( f R g \): g holds on the path until f holds (release)

and the qualifiers

- \( A \): for all computation paths
- \( E \): there exists a computation path

### 2.0 Problem 2 (15%)

1. Show that the periodic tasks \((10,2), (15,5)\) and \((25,9)\) are schedulable using the rate-monotonic algorithm.
2. Show that the periodic tasks \((10,2), (12,5)\) and \((15,4)\) are not schedulable by the rate-monotonic algorithm.
3. Construct the initial segments (enough to show they are schedulable) of a rate-monotonic schedule and an earliest-deadline first schedule of the periodic tasks \((10,2), (15,5)\) and \((25,12)\).

### 3.0 Problem 3 (10%)

A system contains three periodic tasks, \((2.5, 1)\), \((4, 0.5)\), and \((5, 0.75)\) and an aperiodic server \((2,0.5)\). The server is scheduled with the aperiodic tasks rate-monotonically. (Assume that aperiodic server runs the occasional tasks in its time slot, running the current one to completion before starting the next.)

1. What is the total utilization of the three periodic tasks?
2. What is the utilization of the periodic server?
3. Suppose that the periodic server is a basic sporadic server. What are the response times of the following two aperiodic jobs: One arrives at 3 and has execution time 0.75 and the other arrives at 7.5 and has execution time 0.6.
4. Repeat 3 assuming that the periodic server has the same utilization but has a period of 1.