1. Consider the following graph representing a hybrid automaton $H$

1.1 Define the components $H = (Q, X, f, \text{Init}, \text{Dom}, E, G, R)$ of the hybrid automaton

1.2 Verify if $H$ is blocking/non-blocking, deterministic/non-deterministic, Zeno/non-Zeno. Provide a clear justification of your answers.

2. Consider the 2-dimensional switched linear system

\[ \dot{x} = A_\sigma x \]

where the switching signal

\[ \sigma : [0, \infty) \rightarrow \{1, 2\} \]

decides which of the matrices $A_1$ and $A_2$ is active at each time $t$.

2.1 Describe necessary and/or sufficient conditions for the equilibrium $x=0$ to be a globally uniformly asymptotically stable (GUAS) equilibrium of the switched linear system.

2.2 Provide an example of matrices $A_1$ and $A_2$ such that the $x=0$ equilibrium is GUAS.
3. Consider the linear system of order 3 with transfer function

\[ G(s) = \frac{10(s + 10)}{(s + 1)(s^2 + 2s + 10)} \]

where only the output \(y\) is available as a measurement.

Design an output feedback variable structure controller for the regulation of the output \(y\) to some set-point \(y^*\), while preserving the complex eigenvalues of the system in the sliding mode dynamics.

4. Consider the Lur’e system in the figure below

\[ \varphi(\cdot) \]

where

i) \( \varphi(\cdot) \) is a static nonlinearity in the sector \([-k, k]\), with \( k > 0 \)

ii) \( F(s) \) is the transfer function of a first order SISO system and is given by

\[ F(s) = \frac{2500}{(s + 5)(s + 50)} \]

4.1 define the notion of \( L_2 \)-stability for the operator \( H \) with input \( u \) and output \( y \) and discuss its connection with the weakly boundedness of \( H \)

4.2 using the small gain theorem and the circle criterion, estimate the maximum value of \( k > 0 \) such that the operator \( H \) with input \( u \) and output \( y \) is \( L_2 \)-stable with finite gain.
4.3 what about the answer to point 4.2 in the case when function $\varphi(\cdot)$ is known and given by the saturation function plotted below?

![Saturation function diagram](image)

5. Consider the time-varying Lur'e system in the figure below

![Time-varying Lur'e system](image)

where $\varphi(\cdot,t)$ is a time-varying nonlinearity in the sector $[0, k]$, $k>0$, whereas $G(s)$ is the transfer function of a SISO reachable and observable linear system.

Provide the statements of necessary and/or sufficient conditions for its absolute stability.

6. Given the nonlinear regular SISO system of order $n=2$ described by

$$S : \begin{cases} \dot{x} = a(x) + b(x)u \\ y = c(x) \end{cases}$$

Suppose that the relative degree of $S$ in $x^* = 0$ is $r=2$.

Explain in a brief and clear way how to construct a (local) static state feedback linearization that sets the poles of the closed loop system both equal to -1.