Last name **Name** **Student's code (matricola)**

There is no need,
Indeed, it is NOT allowed to use a programmable calculator !

Section 1: TRUE/FALSE QUIZZES

1. The time constant τp of a 1st order system coincides with the time required for the step response to reach 50% from the final value
   True □ false □
2. The damping factor of a 2nd order system can also be negative
   True □ false □
3. The IAE calibration formulas minimize the integral of the error module
   True □ false □
4. If a signal transfer line covers a distance L and the signal travels with a speed v, then its transfer function is G(s)=exp(-(L/v)s)
   True □ false □
5. A feedback controller requires a regular measurement of at least one output variable in order to have the control system working properly
   True □ false □

Section 2: MULTIPLE CHOICE QUIZZES

1. The **Laplace transform** cannot be used to solve:
   - ☐ second order differential equations
   - ☐ linear or linearized differential equations
   - ☐ nonlinear differential equations
   - ☐ linear equations containing time-delayed or lead-time functions

2. Which one of the following definitions does not apply to a **feedback controller**?
a. □ "direct action"
b. □ "reverse action"
c. □ a relay
d. □ FOPDT

3. The PI controller transfer function is
a. □ $G_c=K_c[1+ \tau_I s]$
b. □ $G_c=K_c[1+1/(\tau_I s)]$
c. □ $G_c=K_c[1/(1+\tau_I s)]$
d. □ $G_c=K_c/(\tau_I s)$

4. Which of the following "parameters" is not included in the 2nd order system law?
a. □ Process gain
b. □ *overshoot*
c. □ Natural oscillation period
d. □ Damping factor

5. The offset is:
a. □ $y_\infty - y_{SP}(t)$
b. □ $y_{SP}(t) - y_\infty$
c. □ $y_\infty - y_m(t)$
d. □ Always Positive

Section 3: DYNAMIC REFERENCE MODELS

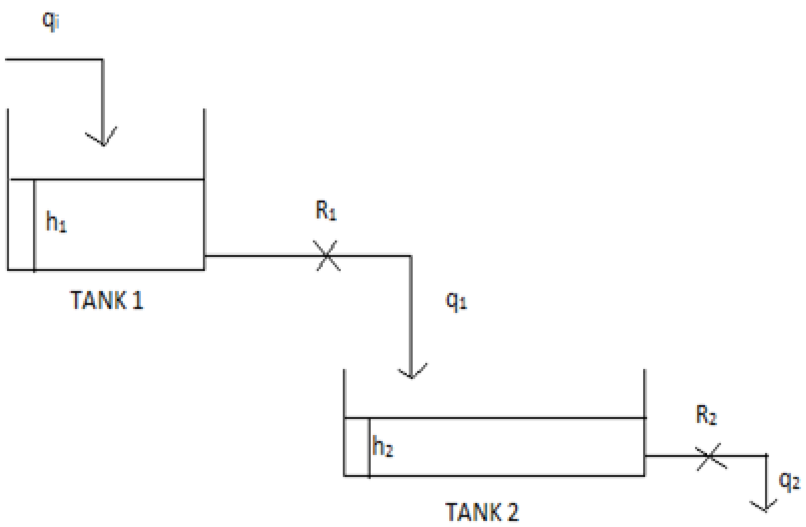
3.1 1st order in series

a. Please recognize and the classify (type, order, etc.) the **dynamical system** determined by the process configuration in figure, where

$\dot{V}_i(t) = q_i(t)$ is the input liquid volumetric feed rate,

$\dot{V}_1(t) = q_1(t)$ is the output volumetric flow rate from the system component 1,

$\dot{V}_2(t) = q_2(t)$ is the output volumetric flow rate from the whole plant



b. Under the assumption of linear outflow from each tank, determine the TF $G(s) = h_2(s)/q_i(s)$

3.2. Forcing functions

Provide

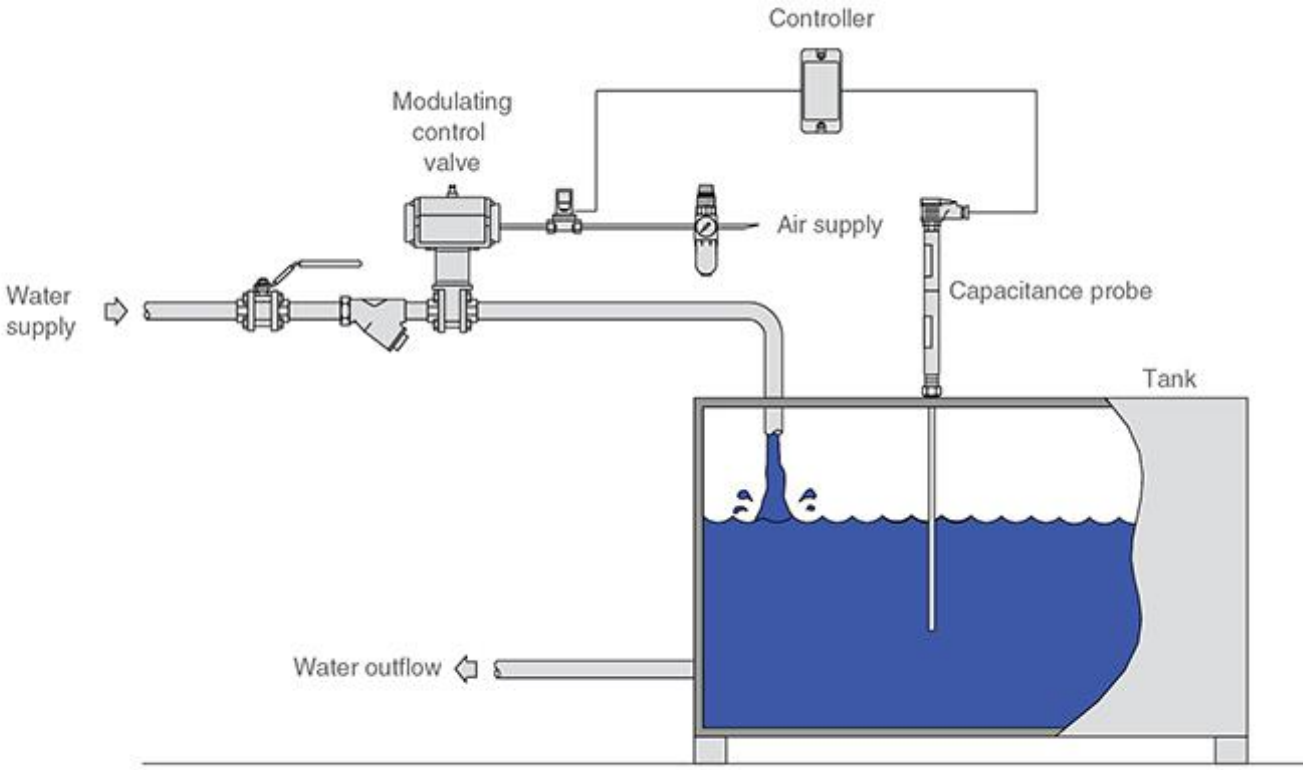
a. a textual description,
b. Then the mathematical formulation,
c. Finally the graphical pattern

for each one of the main forcing functions you consider useful for reference investigation on the dynamical response of linear systems.

Section 4: PROCESS REGULATION AND CONTROL

4.1. Feedback control

The figure introduces a practical application of feedback control in a simplified process drawing.



Among the various process variables (flow rate, etc.)

1. select the **measured variable**
2. select the **controlled variable**
3. select the **manipulated variable**
4. select the **disturbance variable** (if any)

Among the various process **block components** (tank, capacitance probe, etc.)

5. select the **sensor/measuring device**
6. select the **comparator**
7. select the **actuator**
8. select the **final control element**
9. what is the role of the tank in the **control loop system?**

Section 5: CONTROLLERS

5.1. The *relay* controller

a. draw the **error** ε(t) – *controller output* o(t) diagram in presence of **hysteresis**

b. explain <u>briefly</u> what **hysteresis** is

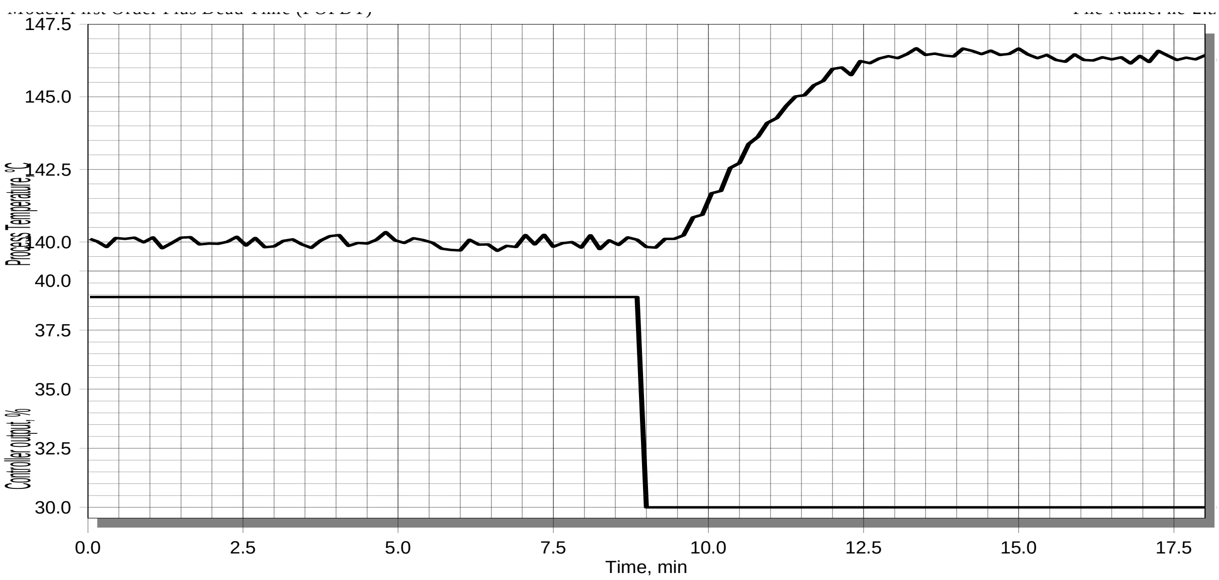
c. provide an application example of a ***relay* controller**

5.2 PID controller tuning

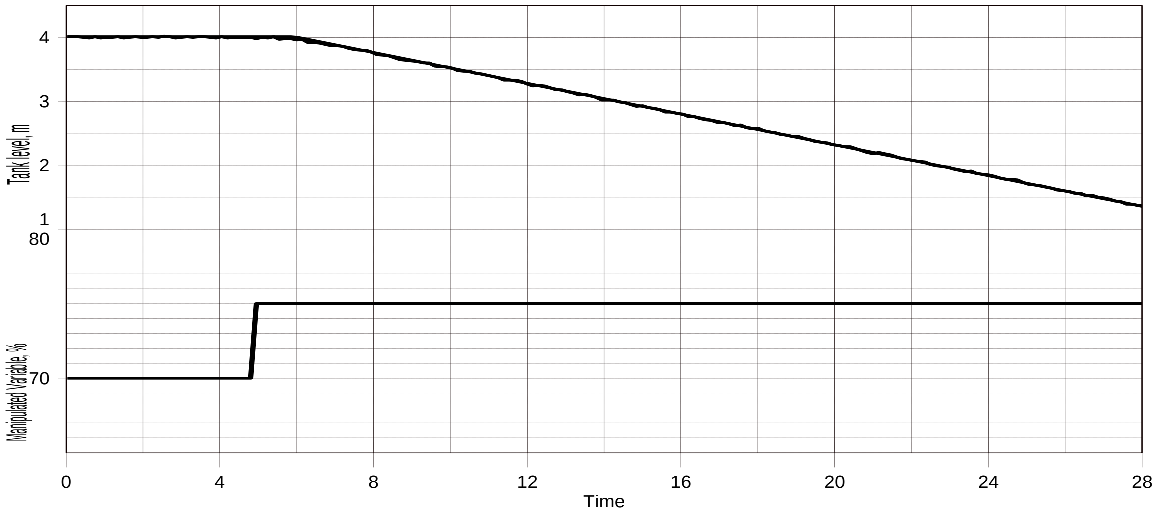
The following diagrams report the **dynamical response** (see the upper curve) to a **step input** (see the lower curve) for three processes whose dynamics is unknown. It is required to tune a **PID** control for each of them.

NOTE: only **<u>qualitative</u>** answers are required: numerical computation need not be performed!

a. Which approximating dynamical model would you adopt for a process giving its step test response as in the following figure?
b. List the parameters involved in this model
c. Which tuning rules do you believe can be used in this case?

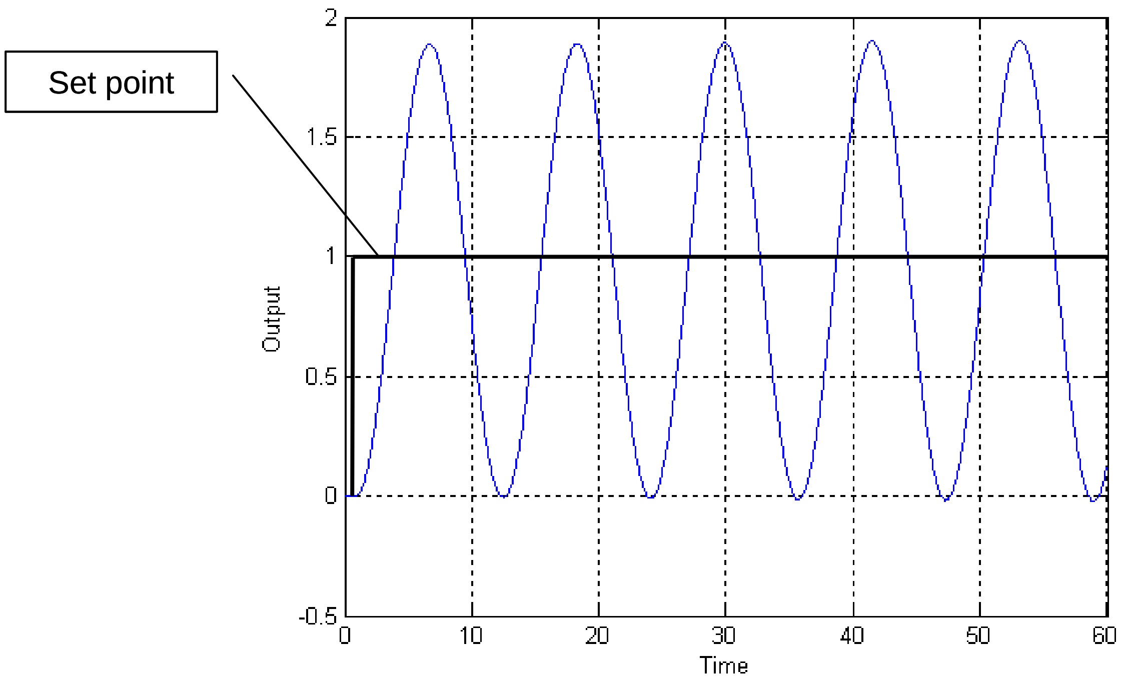


d. Which approximating dynamical model would you adopt for a process giving its step test response as in the following figure?
e. List the parameters involved in this model
f. Which tuning rules do you believe can be used in this case?



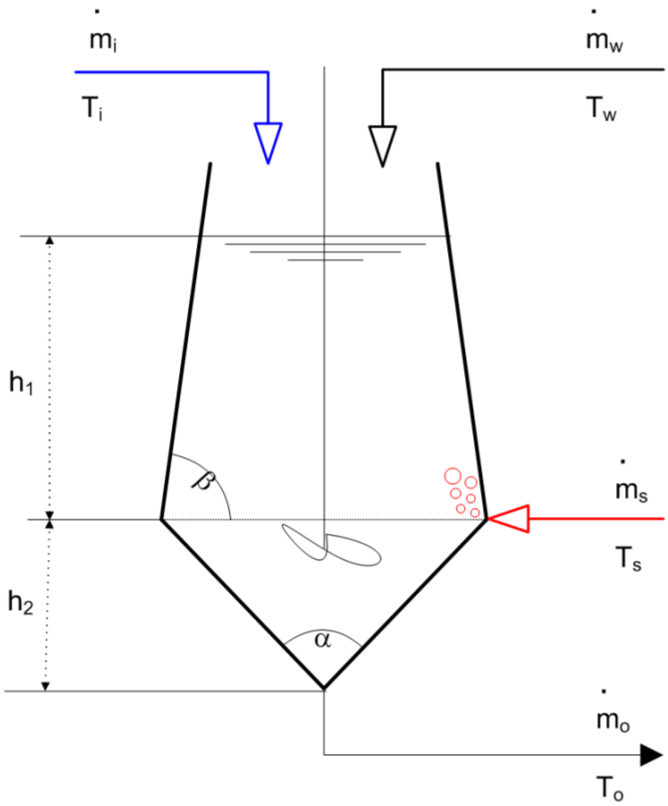
g. Which method has been used to generate this dynamical response (see output) in this third process?
h. List the parameters involved in it

i. Which tuning rules do you believe can be used in this case?



Section 6: MATHEMATICAL MODELS

6.1. Development of a dynamic mathematical model for a lumped parameter system



In a mixer (see figure), a stream of a hot fruit juice at T_w with a feed rate $\dot{m}_w$ is to be thermally tempered.
To this end, it is mixed in the tank with a ground ice stream $\dot{m}_i$ entering at $T_i = 0$ °C, up to a complete fusion of ice, and with a stream of saturated steam entering with a feed rate $\dot{m}_s$ at a temperature maintained always equal to that of the tank, i.e., $T_s = T_o$, up to a complete condensation of steam to water.

The following assumptions hold:

i. The saturated steam condenses completely
ii. The tank is perfectly mixed
iii. The density of liquid ρ is constant
iv. The specific heat of the liquid c_p is constant
v. The feed rate $\dot{m}_w$ is constant
vi. The ground ice flow rate $\dot{m}_i$ is constant
vii. The saturated steam flow rate $\dot{m}_s$ is constant

The variable to be predicted by the model is the liquid temperature $T_o(t)$.

Please reply to the following questions:

1. Can the level h_1 be considered constant: $\neq h(t)$
2. Write the mathematical model in stationary
3. Write the dynamic mathematical model
4. Classify the dynamic mathematical model thus obtained
5. Locate input, status and output variables as well as model parameters
6. Discuss which of the input variables can be taken as a forcing function and reasonably like that, given the nature of the problem
7. Express the model in deviation variables
8. Take, if possible, the dynamic model in canonical form in the domain of time
9. Take the dynamic mathematical model into the Laplace domain
10. Determine the possible transfer function/functions
11. What is the order of the transfer function?