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

There is no need,

Actually, it is NOT allowed to use a programmable calculator !

Sezione 1: QUIZ

1. A process with a **transfer function** that has a positive gain is said to be **direct action**
   true O false O
2. A 4 ÷ 20 mA DC signal is of the "**live zero**" type
   true O false O
3. There is no function in the **time domain** that is the anti-transform of a constant
   true O false O
4. ***offset*** is defined as $y_{SP}(t) - d(t)$
   true O false O
5. **Zero** of a **rational transfer** function is defined as a value of *s* which cancels the denominator
   true O false O

Sezione 2: QUIZ

1. Which of the following is not a *performance criterion* for setting ***TUNING***:
   a. □ *overshoot* minimization
   b. □ evaluation of the minimum of the integral of the error
   c. □ step response with zero tangent to the origin
   d. □ *Decay ratio* = 1/4

2. The **Laplace transform** cannot be used to solve:
   e. □ second order differential equations
   f. □ linear or linearized differential equations
   g. □ nonlinear differential equations
   h. □ linear equations containing a function delayed or anticipated in time

3. Which of the following is not a **final control element**?
   a. □ hydraulic piston
   b. □ pump
   c. □ *relay* controller
   d. □ heating or cooling element

4. The **PD controller** transfer function is:
   a. □ $G_c = K_c[1+ t_d s]$
   b. □ $G_c = K_c[1+1/(\tau_D s)]$
   c. □ $G_c = K_c[1+\tau_D s)]$
   d. □ $G_c = K_c/(\tau_D s)$

5. A **2^{nd} order *underdamped* system** is characterized by a damping factor
   a. □ $\zeta < 0$
   b. □ $\zeta < 1$
   c. □ $0 < \zeta < 1$
   d. □ $\zeta < \frac{\sqrt{2}}{2}$

Section 3: REFERENCE DYNAMIC MODELS

3.1 2^{nd} order systems

For these systems:

a. What is the mathematical model in the time domain?

b. What is the **transfer function**?

c. Define and explain the characteristic parameters.

d. What is the **discriminant** of its characteristic equation?

e. What is the *overshoot*? In what cases does it occur?

f. Calculate the *overshoot* for $\zeta = 0.3$

g. What happens when this system degenerates into an *undamped* one?

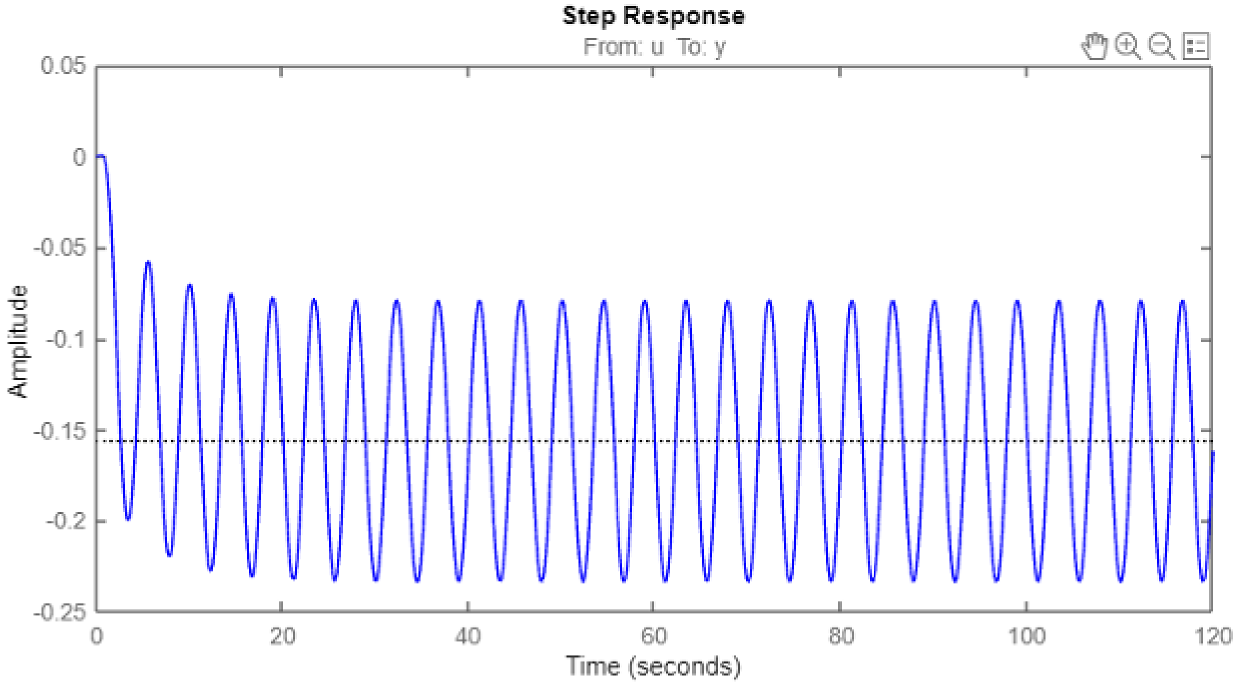
3.2. BIBO stability and time domain responses

a. provide the definition of **BIBO stability**

b. provide the definition of **marginal stability**

c. provide the definition of **unit step or Heavyside function**

The diagram reports in figure the **open loop** step response of a linear dynamical system to unit step.



d. Which stability property has the underlying linear dynamical system?
e. Which type of poles can you guess for the underlying transfer function?
f. Can you estimate the **period** of the oscillating curve? Is it of the order of magnitude of 1 or 10 or 100 s?

Section 4: PROCESS REGULATION AND CONTROL

4.1 Feedback control

The figure introduces a practical application of **feedback control** by means of a simplified P&ID.

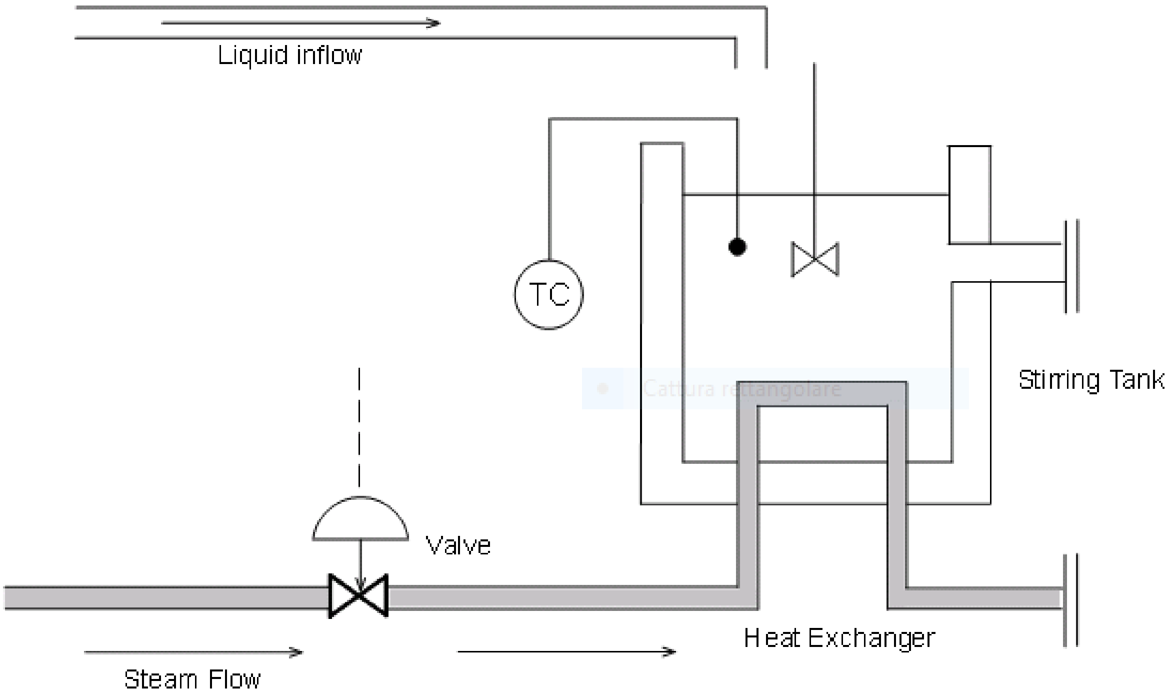


Figure 1: Stirring Reactor with Heat

Among the various variables (flow rate, etc.) you may identify in such a simple process

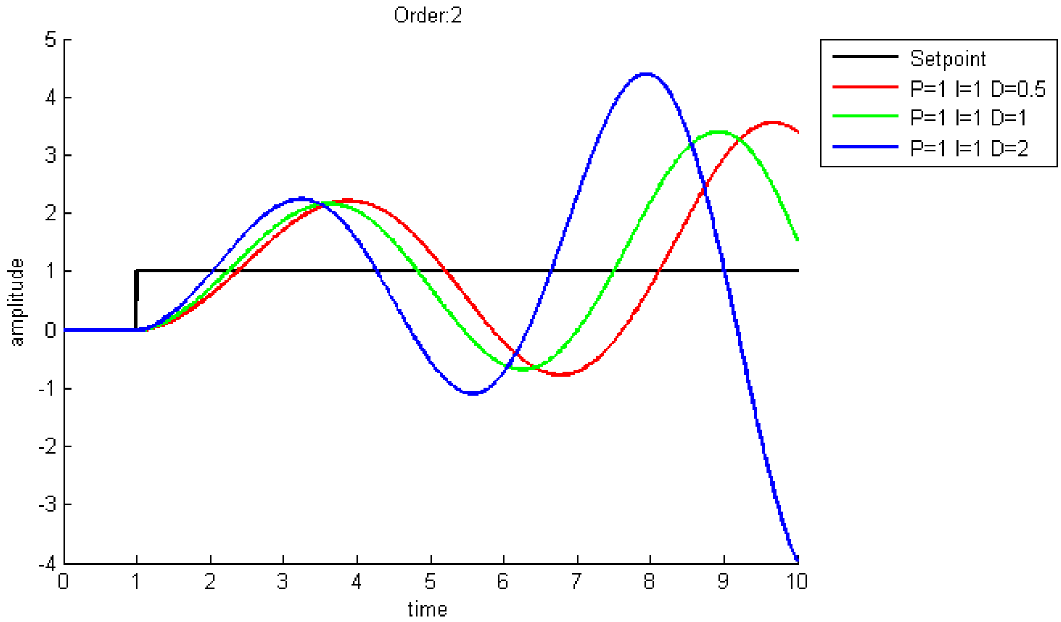
1. identify the **controlled variable**
2. identify the **measured variable**
3. identify the **manipulated variable**
4. identify the **disturbance variable** (if any)

Draw the specific Feedback Block Diagram for this case and put attention to have in it:

5. All the control **block component** blocks that are specific to the case in question
6. All the control **loop variables** that are specific to the case in question

Section 5: CONTROLLERS

The following diagram reports three different closed loop responses to a unit step change in **set point** at a time=1



a. Which type of **controller** is actually used in this closed loop control system?

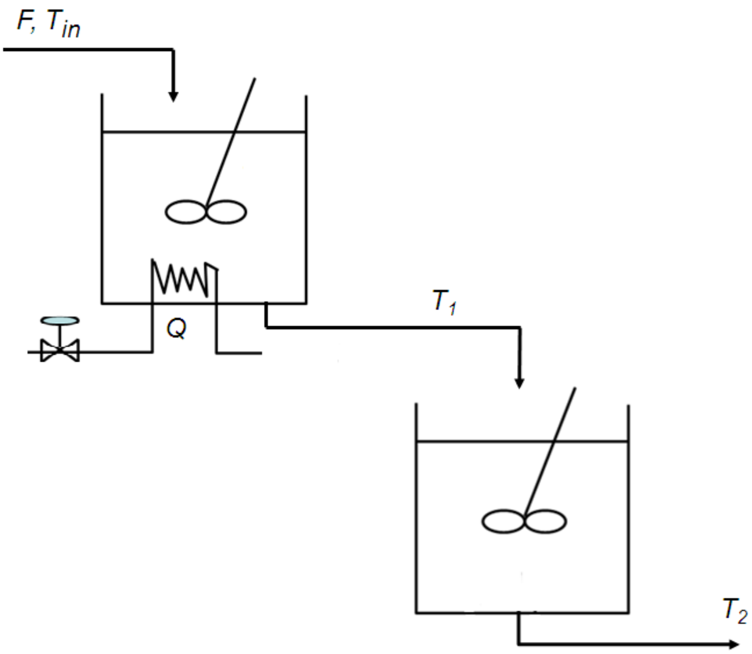
b. What are the **parameters** for which values are reported in the figure caption?

c. What is the most important outcome resulting from the difference in the three colored responses?

Section 6: MATHEMATICAL MODELING

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

An oil stream entering at a temperature $T_{in}(t)$ with a volumetric flow rate F is heated as it passes through two well-mixed tanks in series (see figure). Heat is supplied in the first tank through a heating coil delivering a thermal power Q.



The liquid volumes of both tanks are assumed to be constant.

The following **hypotheses** hold:

1. Perfect mixing in the tanks
2. ρ = constant
3. c_p = constant
4. F = constant [L/s]
5. constant volume of the liquid
6. perfectly insulated tanks

The variable to be predicted with the math model is the temperature $T_2(t)$.

You must:

a. write a **steady state** model
b. write a **dynamical** model
c. classify the obtained **dynamical** mathematical **model**
d. list **input, state, output variables** and the **parameters** of the model
e. discuss which input variables can be assumed as **forcing functions** and which are their possible functional forms for the physical feasibility
f. re-write the model using the **deviation variables**
g. take the model into the Laplace domain
h. reduce the **dynamical** model, if possible, to the **canonical form**
i. determine the **transfer function/s**