Last Name **Name** **student's code**

Section 1: TRUE-FALSE QUIZZES

1. The **time constant** τ_p of a first order system is the time interval which elapses before the step response reaches the 50 % of its final steady-state value
   true ☐ false ☐
2. The **ISE tuning method** requires the minimization of the integral of the error norm
   true ☐ false ☐
3. The **Laplace transform** can be applied to linear dynamical systems only
   true ☐ false ☐
4. In the **servo problem,** the load is constant while the set point is variable in time
   true ☐ false ☐
5. The **zero** of a rational transfer function is a value of s for which the denominator is equal to zero
   true ☐ false ☐

Sezione 2: MULTIPLE CHOICE QUIZZES

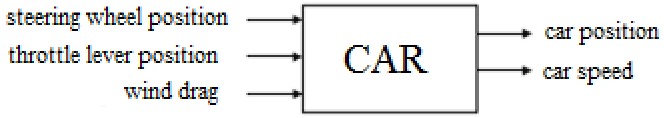
1. An **industrial regulator** can be:
   NOTE: choose the wrong answer!
   a. ☐ a "direct acting" regulator
   b. ☐ an "inverse acting" regulator
   c. ☐ a relay regulator
   d. ☐ a FOPDT regulator

2. Which of the following ones is not an **actuator**?
   a. ☐ hydraulic ram
   b. ☐ centrifugal pump
   c. ☐ *relay* controller
   d. ☐ heating or cooling element

3. The transfer function of a **PD controller** 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. ☐ $G_c = K_c/(\tau_D s)$

4. The **offset** is:
   a. ☐ $y_\infty - y_{SP}(t)$
   b. ☐ $y_{SP}(t) - y_\infty$
   c. ☐ $y_\infty - y_m(t)$
   d. ☐ always positive

5. In the following simplified scheme of a **car automatic control** the **disturbance** is:



a. ☐ steering wheel position
b. ☐ throttle lever position
c. ☐ wind drag
d. ☐ car speed

Section 3: REFERENCE MATHEMATICAL MODELS

3.1. Parametric model

A process is described by the following ODE:

$$3\frac{dy}{dt} + py = 3f(t)$$

where *y(t)* is the **state variable** as a deviated variable, *f(t)* the **input variable** as a deviated variable and p is a **parameter**.

a. What **order** is this dynamic system?

b. Determine the **transfer function**, $G_P(s)$, of this process

c. Assign a suitable value to **parameter** p so that τ_P=1.5 min

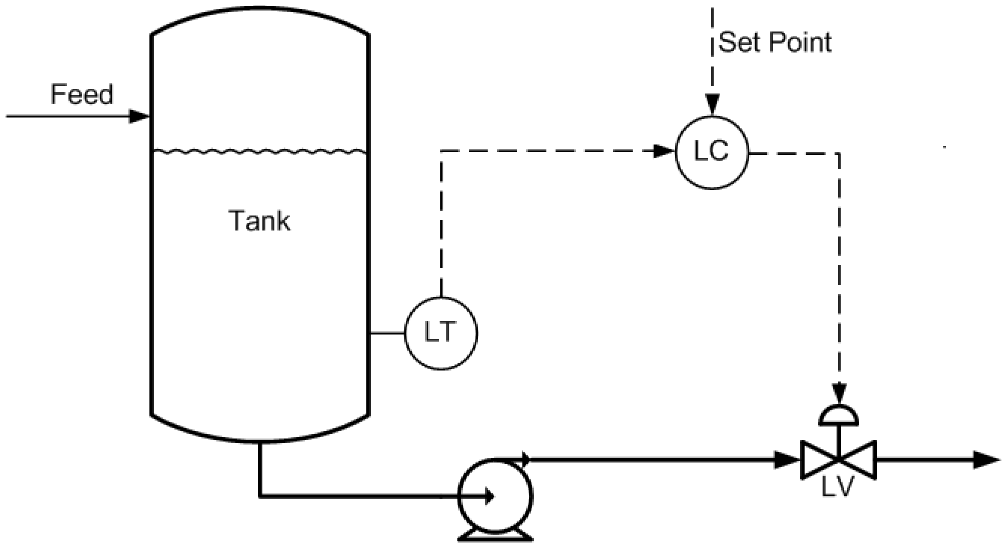
d. Provide an example of **forcing function** *f(t)* which makes **BIBO unstable** this dynamic system

e. Assign another value to **parameter** p so that this dynamic system becomes **purely capacitive**

Section 4: PROCESS REGULATION AND CONTROL

4.1. Feedback control

The figure introduces a practical application of feedback control in a simplified P&ID.



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, valves, pump, 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?**
10. what is the role of the **pump?**

Section 5: CONTROLLERS

5.1. The controller

a. for a **PID controller**, provide the control law in the Laplace domain

b. for a **PID controller**, explain what the controller **bias** is

c. for a **relay controller**, explain briefly what the **hysteresis** is for

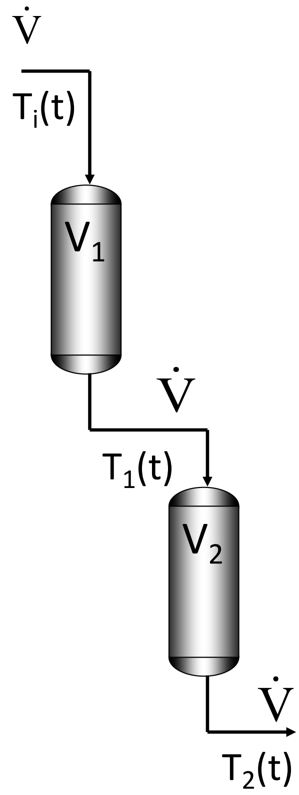
Section 6: MATHEMATICAL MODELLING

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

6.1.a

For the storage and delivery of an aqueous solution of nutraceutical additives in food industry two non-interacting, insulated tanks are used (see Figure).

The aqueous solution enters with a temperature $T_i(t)$ from the top of the tank No.1, with a volume V_1, and leaves with a temperature $T_2(t)$ the tank No.2, with a volume V_2.



The following **hypotheses** hold:

1. Fluid level is constant in each of the 2 tanks
2. The volumetric flow rate $\dot{V}$ is constant
3. Perfect mixing holds in each of the 2 tanks
4. Heat losses are negligible
5. ρ = cost.
6. c_p = cost.

The variable that you want to predict in a dynamic 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 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 this physical problem
f. write the model using the **deviation variables**
g. find the corresponding form of this **dynamical** model in the **Laplace domain**
h. write the **transfer function**
i. **classify** the **transfer function**

6.1.b

Later, a modification is introduced for the storage and delivery of the aqueous solution of nutraceutical additives in food industry with one insulated tank followed by an insulated, long, small-diameter pipe **coil** of overall length L and of negligible volume (see new Figure below).

The variable that you want to predict in a dynamic model is still the exit temperature $T_2(t)$.

You must:

j. Write a **dynamical** model
k. write the **transfer function**
l. discuss and compare the **transfer function** between the case 6.1.a and 6.1.b