Surname **Name** **Matricola**

Section 1: TRUE/FALSE QUIZ

1. In a process, a **transfer function** having a positive gain is called **direct acting**
   true □ false □
2. In the **servo problem**, the load is constant while the set point is variable in time
   true □ false □
3. In a **transfer function** G(s), the variable *s* belongs to the field of real numbers.
   true □ false □
4. The ***offset*** is defined as $y_{SP}(t) – y_m(t)$
   true □ false □

Section 2: MULTIPLE CHOICE QUIZ

1. What is not a **final control element**?
   a. □ hydraulic piston
   b. □ pump
   c. □ relay controller
   d. □ heating element

2. What is not a parameter of the control law of the **PID controller**?
   a. □ bias
   b. □ integral time
   c. □ derivative time
   d. □ process gain

1. What is not a **TUNING performance criterion** between the following?
   a. □ overshoot minimization
   b. □ evaluation of the minimum of the error integral
   c. □ zero tangent at the origin of the input step response
   d. □ Decay ratio = 1/4

3. The **transfer function** of a PI controller 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. When the K_c of a PID controller is doubled, the **rise time** of the unit step response in a closed loop
   a. □ does not change
   b. □ doubles
   c. □ decreases

d. □ increases

Section 3: REFERENCE DYNAMIC MODELS

3.1 1st order systems in series

a. Determine the **transfer function** for two **non-interacting** tanks in series

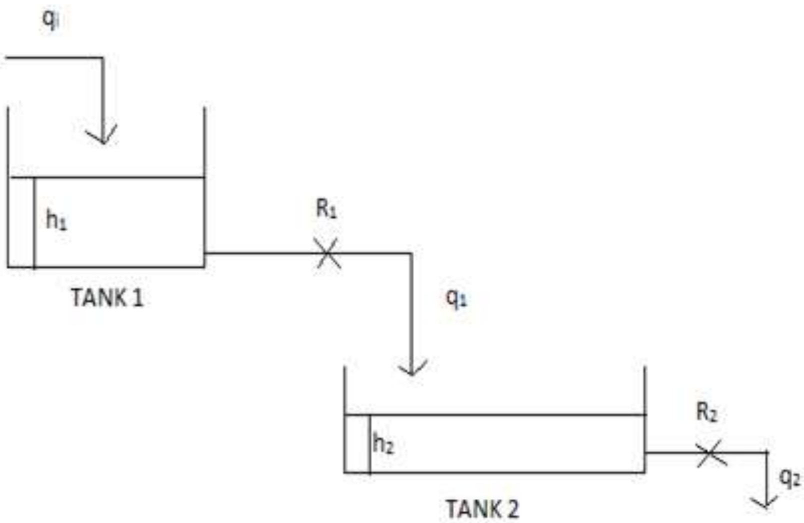


Figure 1. Non-Interacting Tank System

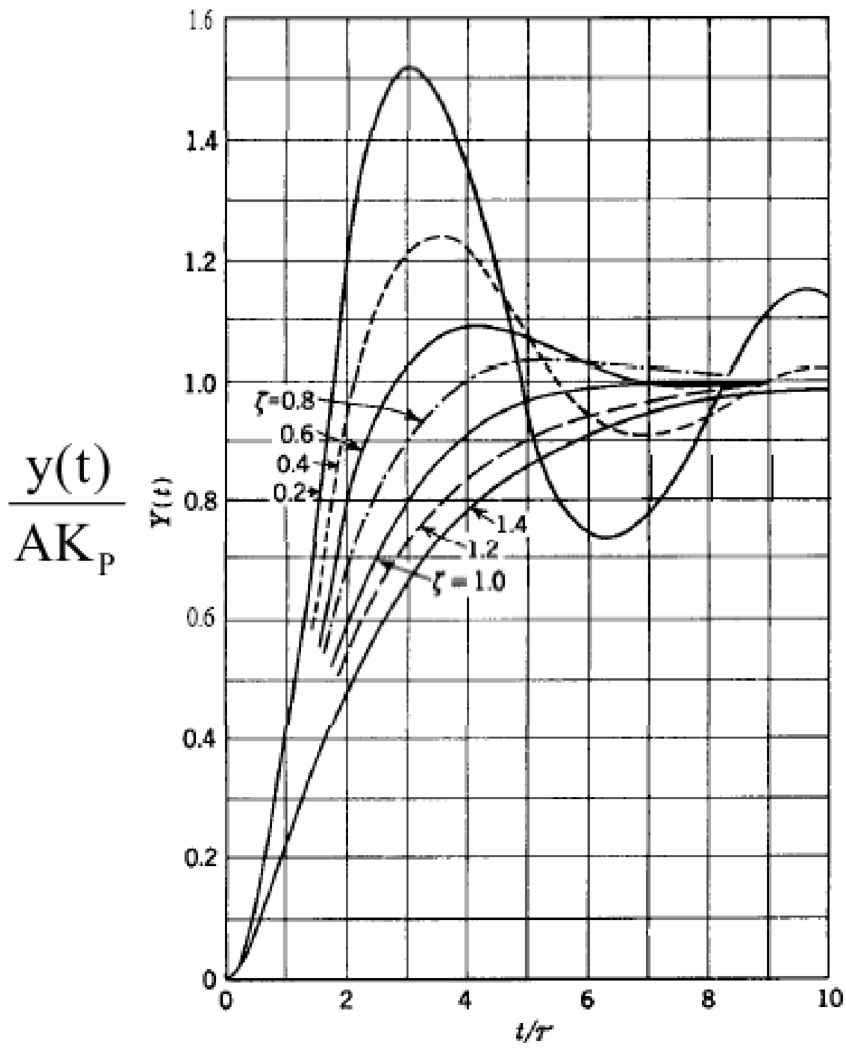
b. What is the **transfer function** of N non-interacting systems in series, each having its own TF $G_i(s)$?

3.2. Properties of the 2nd order dynamic response

A **2nd order linear dynamic system** has a **static gain** $K_p = 2.25$, a **time constant** $\tau = 1.3$ s, a **damping factor** $\zeta = 0.2$. For a **unit step input response**:

a. what is the value of the dynamic response after a time t = 3.7s?
b. what is the **overshoot**?
c. what is the value of the **overshoot**?
d. what is the **decay ratio**?
e. what is the value of the **decay ratio?**
f. what is the value of the **period of oscillation**?
g. what is the value of the **rise time**?
h. if $\zeta = 0.6$, what will be the value of the **overshoot**?

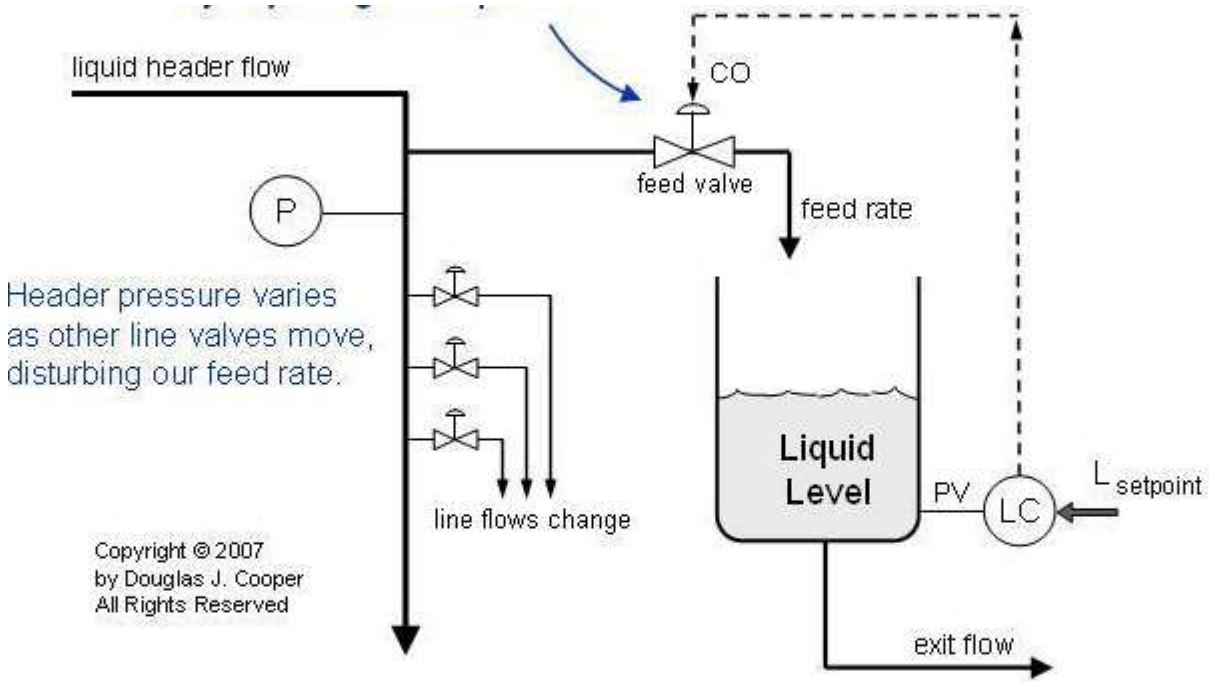
NOTE: you can use the dimensionless diagram of the dynamic response to the step input change



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, valves, impeller, 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 PID controller

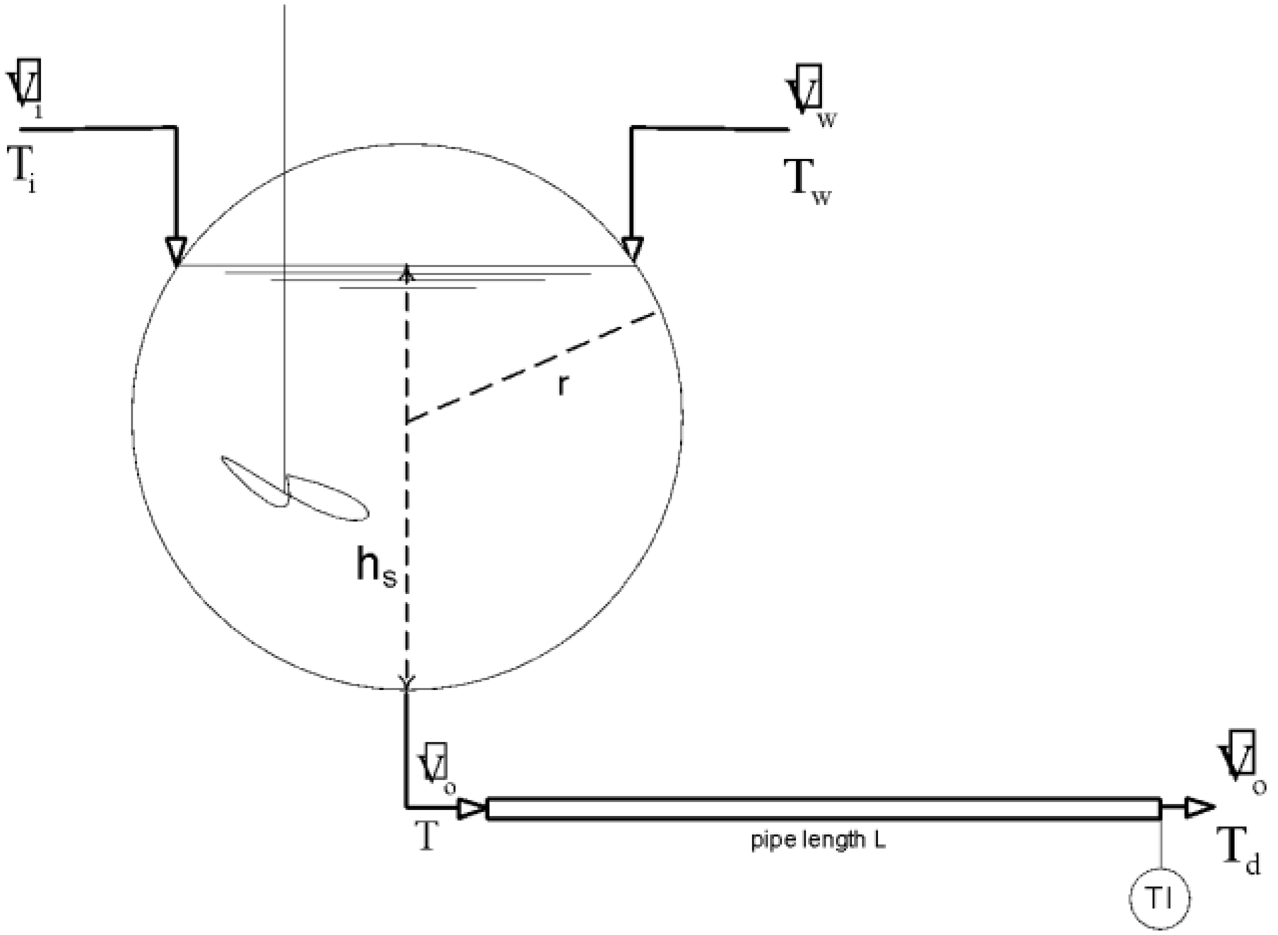
a. provide the definition of **error** $\varepsilon(t)$ supplied to the controller

b. explain what the controller **bias** is

Section 6: MATHEMATICAL MODELLING

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

The system in the figure is used for the addition of fresh water, with a volumetric flow rate $\dot{V}_w$ and temperature T_w, to warm salt water that enters from above with a volumetric flow rate $\dot{V}_i$ and temperature T_i (t), and exits at the center of the convex bottom with a volumetric flow rate $\dot{V}_o$ at temperature T(t).



The variable, which you want to predict by the model, is the temperature $T_d(t)$ measured "at distance" after a long pipe of length L and of negligible volume.

The following **hypothesis** are assumed:

1. The water temperature T_w is constant
2. The liquid density ρ is constant
3. The liquid level h_s is constant
4. The tank is perfectly mixed

5. The pipe is perfectly insulated
6. The specific heat c_p of the liquid is constant

You must:

a. write a **steady state model**

b. write a **dynamical model** in the **time domain**

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 dynamic model in terms of the **deviation variables**

g. put the **dynamical model** in the **canonical form**

h. transpose the dynamic model into the **Laplace domain**

i. obtain the **transfer function**