Surname **Name**

Section 1: TRUE/FALSE QUIZZES

1. The **ITSE criterion** is based on the integral of the time-weighted absolute error
   true ☐ false ☐
2. The inverse Laplace transform of a constant does not exist in the **time domain**
   true ☐ false ☐
3. The output variable of a **relay controller** always assume an even number of values
   true ☐ false ☐
4. The dynamic response of an input step change of a system controlled by a **P-only controller** always shows an **offset**
   true ☐ false ☐

Section 2: MULTIPLE CHOICE QUIZZES

1. If **τ** is the **characteristic time** of a self-regulating first-order system to which an input step test is applied, the 99% of the **new steady state value** for the output is reached after at least:
   a. ☐ τ
   b. ☐ $3\ \tau$
   c. ☐ $5\ \tau$
   d. ☐ $7\ \tau$

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

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. Which among the following ones is not a **TUNING performance criterion**?
   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

Section 3: REFERENCE DYNAMIC MODELS

3.1. A parametric model

The dynamics of a process is described by the following **transfer function (TF)**:

$$G_{\mathrm{p}}(s) = \frac{3s + 7\mathrm{q}}{s^2 + \mathrm{p}s + \frac{7}{9}}$$

where p and q are two **parameters**.

a) Which is the **order** of this system?

b) Assign a suitable value to **parameter** q such that the **TF** has a **zero** equal to -3

c) Assign a suitable value to **parameter** p such that the **TF** has 2 **coincident poles**

d) What is the **static gain** K_{p} as a consequence of the assigned values of p and q?

e) Find the **poles** of $G_{\mathrm{p}}(s)$

f) Assign a new value to **parameter** p such that the corresponding dynamical system is **undamped**

g) Find the **poles** of $G_{\mathrm{p}}(s)$ obtained for this latter case

h) Draw a quantitative plot in which the step-test response for this latter system is shown

i) What happens to the dynamic system if p < 0?

3.2 FOPDT model

a. Show the **characteristic parameters** and write the transfer function.

b. Is it a **linear model**?

c. It can also be defined as a model of **systems in series**. Why?

d. How would you classify its **general dynamical behavior in an open loop**?

e. Draw a quantitative plot of its response to a step variation of the input variable.

f. Illustrate an **example of a real system** in process engineering whose transfer function is well approximated by a FOPDT model

3.3. Stability of dynamic system

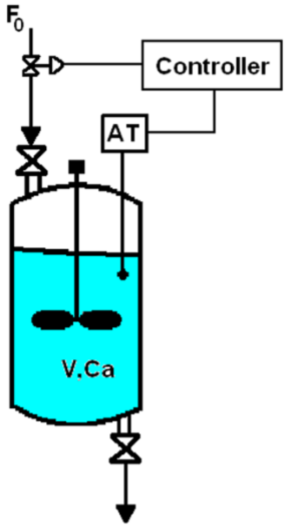
a. provide the definition of **BIBO stability**

b. does the **BIBO stability** apply to time-domain or Laplace-domain 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, 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. Controller tuning

a. What is tuning?

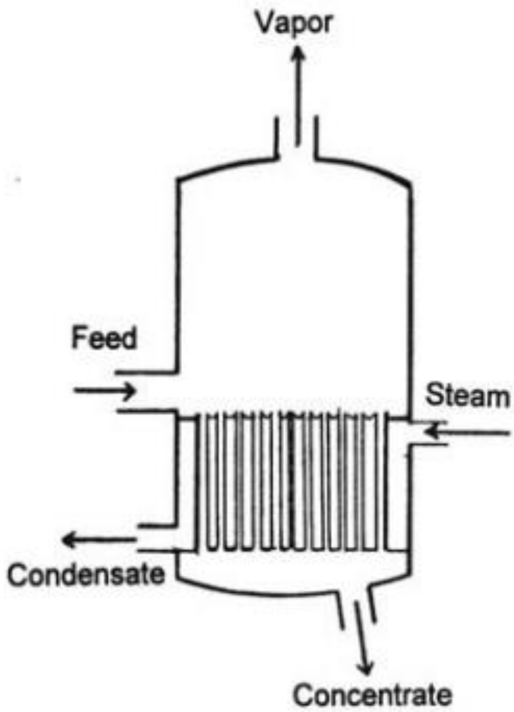
b. For which type of controllers is **tuning** required?

c. Describe briefly and schematically the controller tuning procedure that is adopted in a **closed loop** configuration.

Section 6: MATHEMATICAL MODELING

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

A calandria evaporator (see Figure) concentrates a saline solution (feed) that enters with a mass flow rate $\dot{m}_{in}$ at a temperature T_{in}; leaves with a mass flow rate $\dot{m}_{out}$ and, obviously, a greater salt concentration; evaporates water with a mass flow rate $\dot{m}_v$.
The evaporator is a circular section, has a conical V_C volume bottom always full of the solution, a cylindrical body of cross-section A, a calandria that is installed inside the cylindrical body, consists of a tube bundle (always submerged) that it occupies a V_T volume and has an exchange surface S.
The thermal power $\dot{Q}$ required for evaporation is supplied by a saturated condensing steam with a mass flow rate $\dot{m}_{st}$ at a temperature T_{st}.



The variable that is intended to be predicted by a dynamic model is the temperature T(t) of the saline solution inside the evaporator.

The following **hypotheses** hold:

I. Perfect mixing of the liquid in the evaporator
II. The evaporator is perfectly insulated and there are no thermal losses to the outside
III. The liquid density ρ is constant
IV. The latent evaporation heat of the saline solution λ = const.
V. The specific heat of the saline solution c_p = const.
VI. The Global thermal exchange coefficient U = const.
VII. The liquid level in the evaporator is constant
VIII. The thermal power $\dot{Q}$ supplied by condensing steam for saline water evaporation is constant

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

ADDENDUM

The VIII assumption is no longer valid and is replaced by the following one:

VII bis the mass flow rate of the condensing steam $\dot{m}_{st}$ is changing with time

11. What changes in the dynamic mathematical model thus obtained?