Surname **Name** **Student's code.:**

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

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 63.2 % of its final steady-state value

   true ☐ false ☐

2. A system with complex conjugate poles is BIBO unstable.

   true ☐ false ☐

3. The steady-state error of a feedback-controlled system is the difference between the desired output and the actual output as time goes to infinity.

   true ☐ false ☐

4. A rational transfer function can account for dead times.

   true ☐ false ☐

Section 2: QUIZZES

1. The PID controller transfer function is

   a. ☐ $G_c=K_c[1 + \tau_D s + \tau_I s]$
   b. ☐ $G_c=K_c[1 + \tau_D s + 1/(\tau_I s)]$
   c. ☐ $G_c=K_c[1/(1+\tau_I s)+ \tau_D s]$
   d. ☐ $G_c=K_c/((\tau_{I+}\tau_D) s)$

2. The Laplace transform cannot be used to solve
a. ☐ second order differential equations
b. ☐ linear or linearised differential equations
c. ☐ nonlinear differential equations
d. ☐ higher-order linear differential equations

3. In a critically damped second order system, the damping factor is equal to
a. ☐ $\zeta > 1$
b. ☐ $\zeta < 1$
c. ☐ $\zeta = 0$
d. ☐ $\zeta = 1$

Section 3: REFERENCE DYNAMIC MODELS

3.1. Response of a dynamic model

A first-order dynamic system, with unknown parameters, is disturbed by

i. a step input with amplitude A=3.5 and

ii. a unit impulse input.

The dynamic response in both cases is y(t)=8 at the dimensionless time t/τ=1.5.
By using the generalized diagrams attached here, please calculate:

a. static gain;

b. time constant;

c. the value y(0) of the dynamic response to unit impulse input at the origin (t/τ=0).

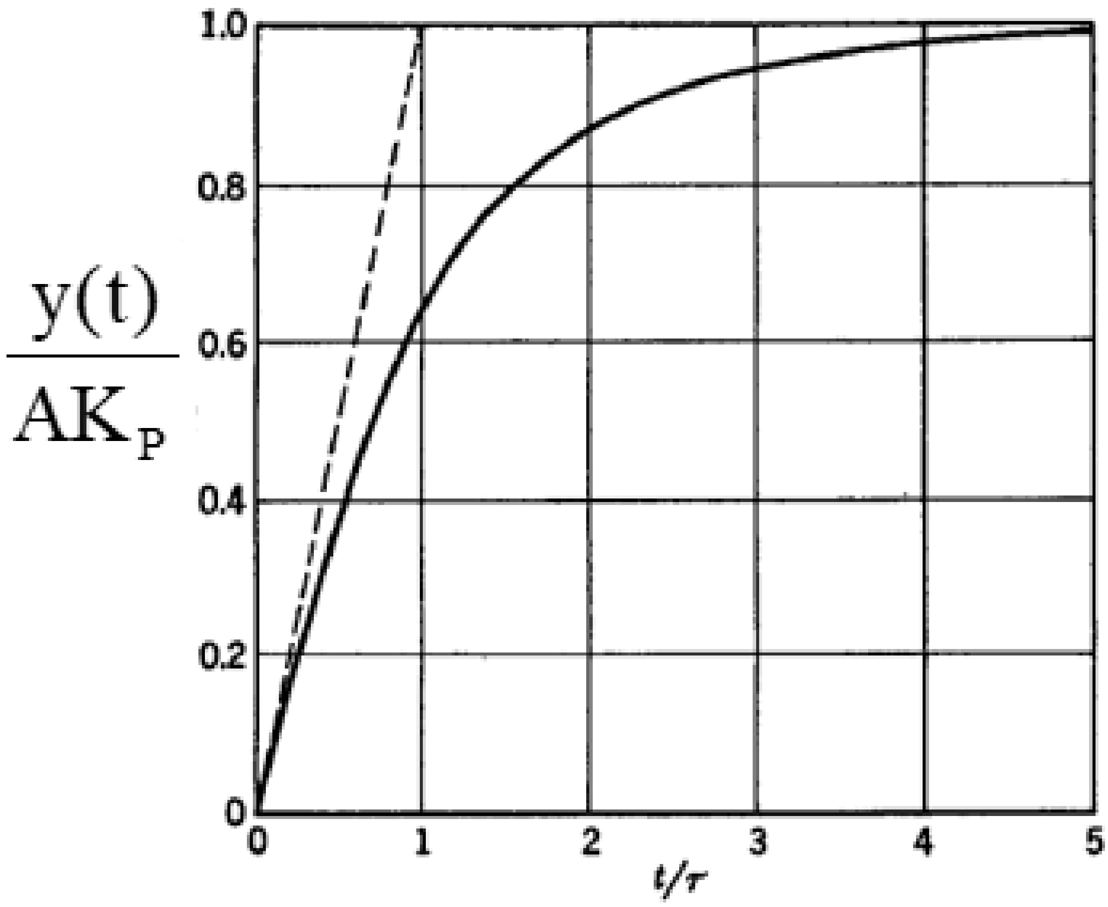


Figure 1. Response of a first order system to a step input of amplitude "A"

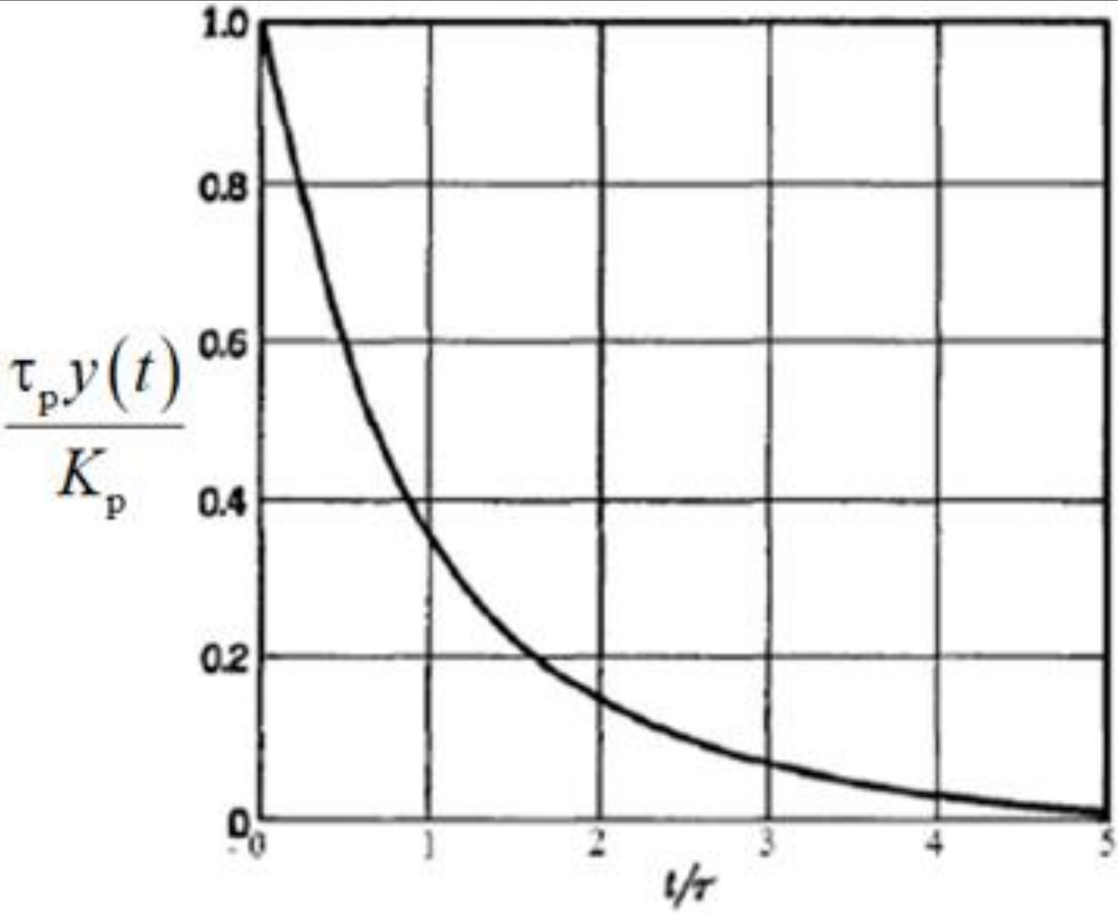


Figure 2. Response of a first order system to a unite impulse

3.2. Parametric model

The dynamics of a process is described by the following transfer function:

$$G_P(s) = \frac{ks + 2}{s^2 + 5s + 6}$$

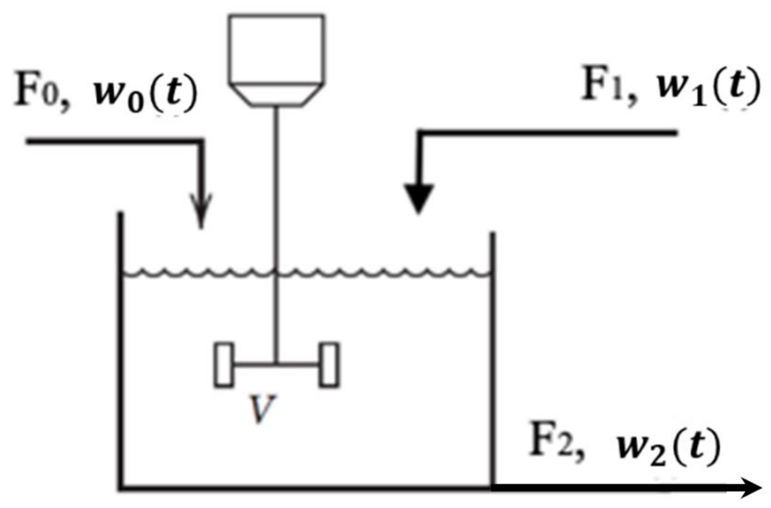
where k is a **parameter**.

a) What order is this dynamic system?
b) How much is the static gain K_p?
c) How much, if any, is the damping factor (ζ) at the denominator?
d) Assign a suitable value to the parameter k so that the numerator has a zero equal to a pole

Section 4: CONTROL AND MONITORING

4.1. The feedback control

A feedback control has to be performed on a perfectly mixed continuous mixer (see the figure) to assure a continuous production of a diluted solution at mass concentration w_2. The mixing is performed between the main stream F_0 with mass fraction w_0 and a less concentrated solution F_1, with mass fraction w_1.



The manipulated variable is the flow rate of diluting stream F_1.

1. propose, on the same drawing, **the P&ID**
2. select the **controlled variable**
3. select the **disturbance variable** (if any)
4. draw the **block diagram (for this particular) process control**

Among the various process **block components** (tank, valves, motor, etc.) individuate on the P&ID (sketched as an answer to the above question 1.) the characteristic variables of automatic control present in this process:

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

Section 5: CONTROLLERS

A process has the following transfer function:

$$G_P(s) = \frac{1}{5s+2}\exp(-s)$$

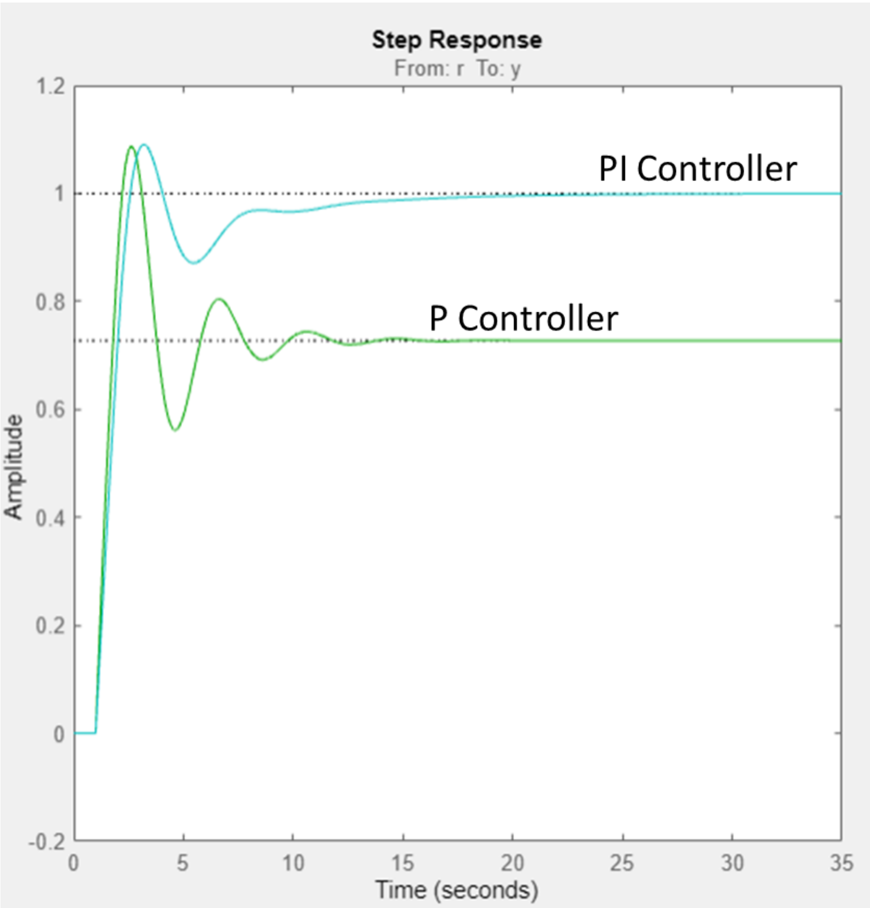
1. How much is the gain of the process (K_P)?

2. Which is the time constant of the process (τ_P)?

3. Is the process affected by delay (t_d)? If so, quantify it.

4. The process is to be feedback controlled. Calculate the **tuning parameters** for a PI controller.

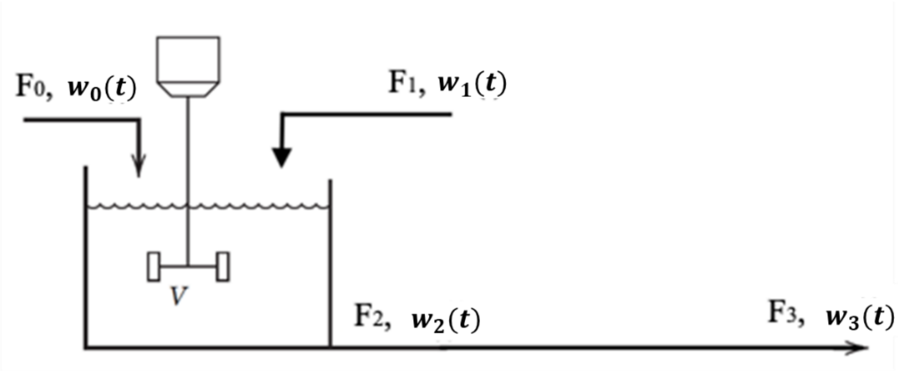
The following figure shows the **closed loop** response of the above process to a unit step change of the **set point** (see the value Amplitude=1 on the y-axis).
Two different configurations were chosen, i.e., the above PI controller and a P controller as an alternative:



5. The Head of the Process Engineering Team prefers using a proportional–integral type. Explain why.

Section 6: MATHEMATICAL MODELLING OF A LUMPED PARAMETER SYSTEM

A perfectly stirred, constant-volume tank mixer has two input streams, both consisting of diluted solutions a water and a solute. The mass fraction (w [=] $\left[\frac{kg_{solute}}{kg_{solution}}\right]$) of the solute of both the inlet streams can vary with time, whereas the solution mass flow rates F_0, F_1 and F_2 are constant. The physical properties can be assumed constant, and the output line is relatively short, so that a negligible time delay for this line can be expected $\left(w_3(t) = w_2(t)\right)$.



You must

1. write the **dynamical model** of the system;
2. write the **steady state** model of the system;
3. list **input**, **state**, **output** variables and the **parameters** of the model;
4. is the dynamical model a linear model? If not, **individuate and indicate the non-linear terms**.
5. **write the model in the Laplace domain;**
6. **obtain the transfer functions** describing the relation between the input and output variables;
7. **classify the obtained transfer functions** and individuate the parameters.

A maintenance intervention on the plant modifies the path of the output line, increasing its length with respect to that in the above Figure. Therefore, the assumption of negligible time delay t_d for the output line does not hold anymore and it is $\left(w(t) \neq w_2(t)\right)$.

In such a new situation you must:

8. Write the **dynamical model** of the system;
9. **write the model in the Laplace domain**;
10. **obtain the transfer functions** describing the relation between the input and output variables.