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. A process with a transfer function having a negative gain is said to be reverse acting

   true ☐ false ☐

2. In a servo problem the aim is to track the time varying set-point.

   true ☐ false ☐

3. The damping factor of a 2nd order system can also be negative

   true ☐ false ☐

4. The zero of a rational transfer function is a value of s for which the denominator vanishes

   true ☐ false ☐

Section 2: QUIZZES

1. Which controller action usually ensures **zero offset** from the desired set point?
   a. ☐ pneumatic
   b. ☐ proportional
   c. ☐ integral
   d. ☐ derivative

2. The PI controller transfer function 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. ☐ $G_c=K_c/(\tau_I s)$

3. The integral action, which is part of a PID algorithm, is often called:

   a. ☐ rate
   b. ☐ reset
   c. ☐ gain
   d. ☐ insert

Section 3: REFERENCE DYNAMIC MODELS

3.1. Response of a dynamic model

A thermometer has first-order dynamics with a time constant of 1 second, steady-state gain of 1.

It is placed in a temperature bath at 120°F (T_{ext}). After the thermometer reaches steady state (T_{ext}=T_m=120°F), it is suddenly placed in a bath at 140 °F for $0 \leq t \leq 10$ s. Then T_{ext} is returned to the bath at 100 °F.

$$T_{ext}(t) = 120 + 20\,u(t) - 40\,u(t-10)$$

Where $u(t)$ is the Heaviside step function.

1. Write the forcing function $T_{ext}(t)$ in terms of deviation variable(s) $T'_{ext}(t)$.
2. Write the forcing function $T'_{ext}(t)$ in the Laplace domain ($\hat{T}_{ext}(s)$).
3. Obtain the expression, in the Laplace domain, of the measured temperature $\hat{T}_m(s)$.
4. Obtain the expression of the time evolution of the measured temperature in terms of deviation variable T'_m(t)
5. Calculate the measured temperature at:
   a. t=0.5 s;
   b. t=10.5 s;
   c. t=15 s.

x	*exp(-x)*
0	1.00
0.25	0.78
0.5	0.60
0.75	0.47
1	0.37
1.5	0.22
2	0.14
2.5	0.08
3	0.05
3.5	0.03
4	0.02
≥ 4.5	0

Hints:

- The $\mathcal{L}^{-1}\{e^{-t_d s} f(s)\} = u(t-t_d) f(t-t_d)$ where $u(t)$ is the Heaviside step function.
- The provided table can be used to approximate the exponential decay function:

3.2 Stability of dynamic system

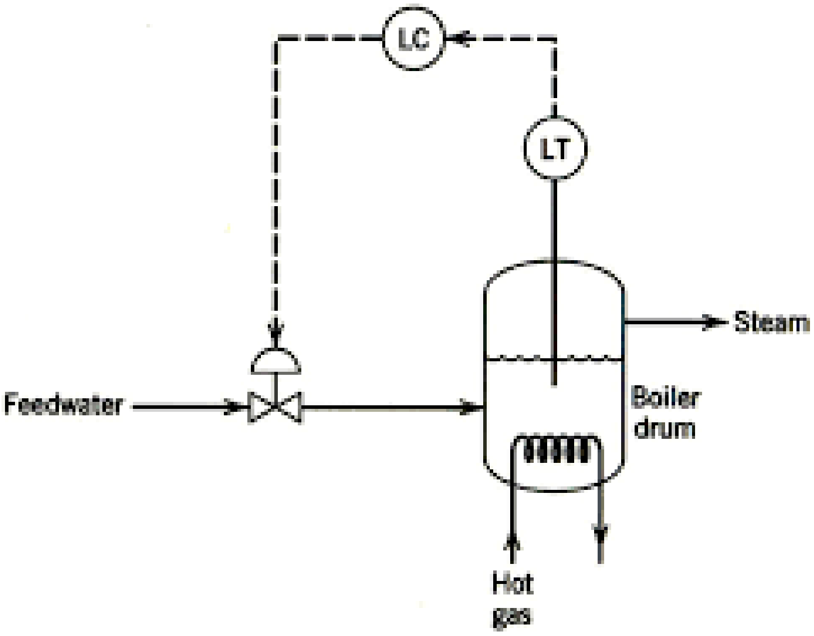
a. provide the definition of **BIBO stability**

b. does the **BIBO stability** apply to time-domain or Laplace-domain systems?

Section 4: CONTROL AND MONITORING

4.1. The feedback control

The figure shows a practical application of feedback control.



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)

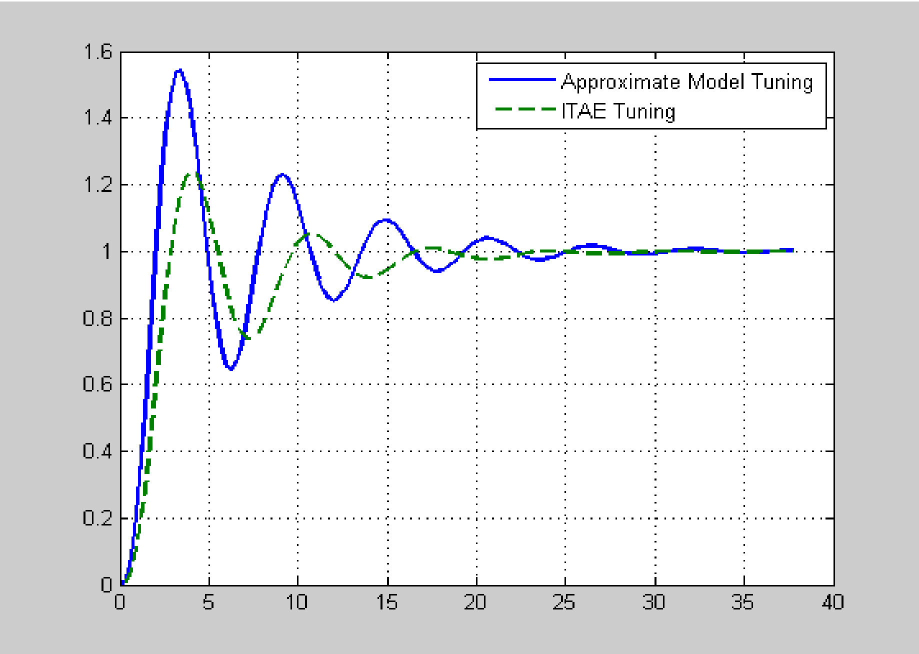
Among the various process **block components** (tank, valves, pump, etc.)

5. select the **sensor/measuring device**
6. select the **comparator**
7. select the **actuator**
8. select the **final control element**
9. what 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

5.1 Tuning the PID controller

A **PID** controller is subjected to a first *tuning* procedure (*Approximate Model tuning*) and the dynamic system controlled by it at closed loop is subjected to a *step* response in the *set point* (see the **dynamic response** with a continuous curve in fig.).



Then, the same **PID** controller is subjected to an ITAE *tuning* procedure and the dynamic system controlled by it at closed loop is again subjected to a *step* response in the *set point* (see the **dynamic response** with dashed curve in fig.).

a. What is the ITAE formula?

☐ $\int_0^\infty e^2 dt$ ☐ $\int_0^\infty |e| dt$ ☐ $\int_0^\infty te^2 dt$ ☐ $\int_0^\infty t|e| dt$

b. Which one of the 2 **dynamic responses** is better (and why)?

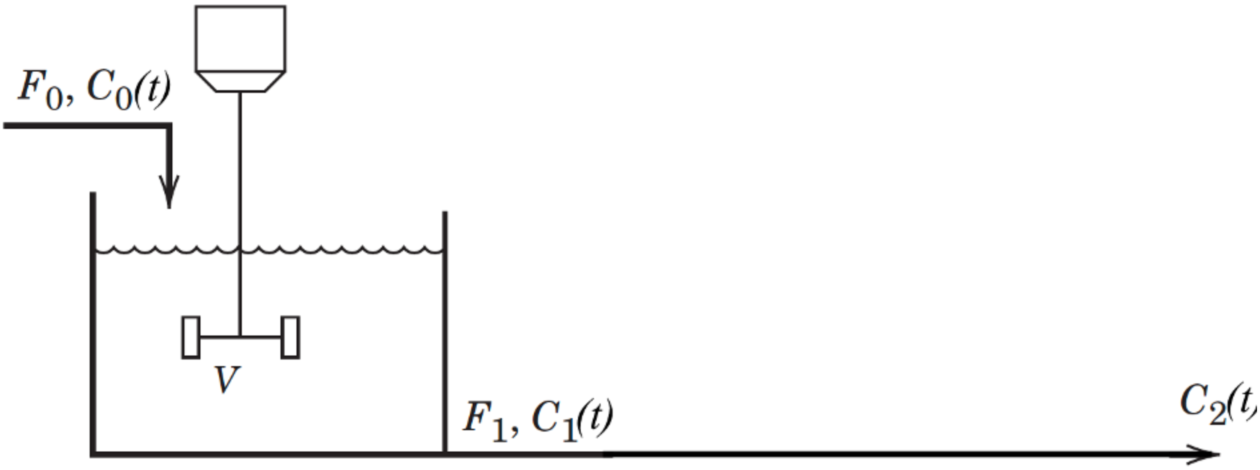
Type your answer here!

c. Discuss (qualitatively) the characteristics of **dynamic response** with ITAE *tuning*.

Type your answer here!

Section 6: MATHEMATICAL MODELLING

Consider the following isothermal reactor. A second-order reaction A → B occurs with reaction rate constant k. The volumes of liquid in the reactor, V, is constant; the flow rates F0, F1 are constant as well. 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 ($C_2(t) = C_1(t)$).



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 linearize the non-linear term(s);**
5. **write the model in the Laplace domain;**
6. **obtain the transfer function** describing the evolution of $C_2(s)$ with respect to the input variable(s);
7. **classify the obtained transfer function** and individuate the parameters.

A maintenance intervention on the plant modifies the path of the output line, increasing its length. Therefore, the assumption of negligible time delay t_d for the output line does not hold anymore and it is ($C_2(t) \neq C_1(t)$).

You must:

8. Write the **dynamical model** of the system;
9. **write the model in the Laplace domain**;
10. **obtain the transfer function** $G(s)=C_2(s)/C_0(s)$