ORDRE DES INGÉNIEURS DU QUÉBEC

MAI 2017 SESSION

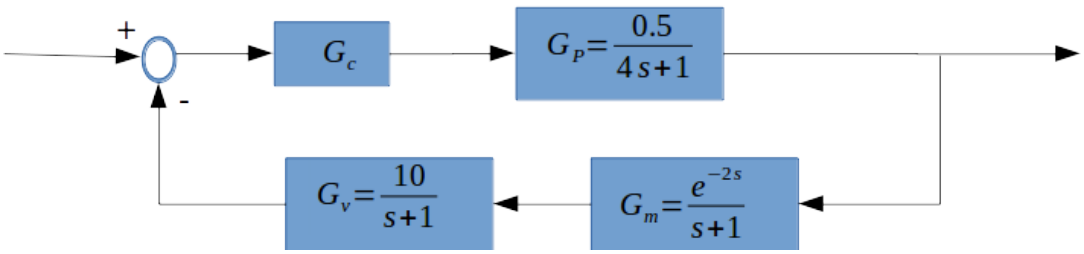
Open-book examination
Calculators: only authorized models
Duration : 3 hours

16-CH-A6 Process dynamics and control

All 4 questions have a value of 25 %

Question 1 (25 points):

a) (5 points) Write the characteristic equation for the process with a proportional (P) controller.

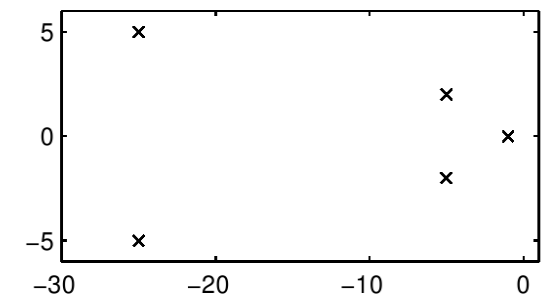


b) (10 points) Use the Routh criterion to find the maximum P controller gain. Use Padé first order approximation.

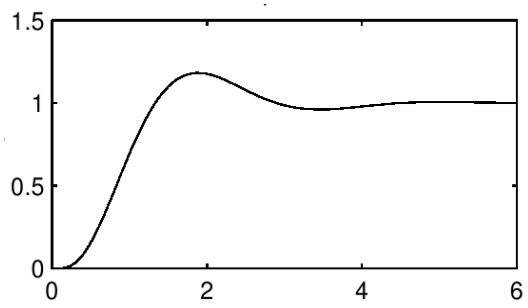
c) (10 points) Find the stability limit using direct substitution.

Question 2 (25 points):

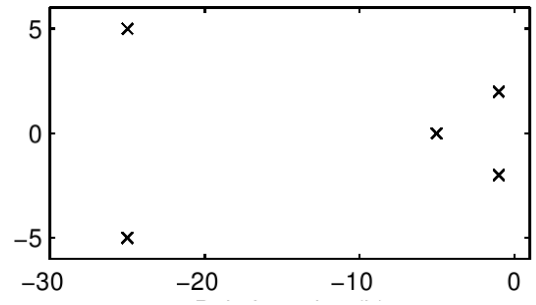
a) (10 points) Associate the response to the systems complex plane poles in the following figures :



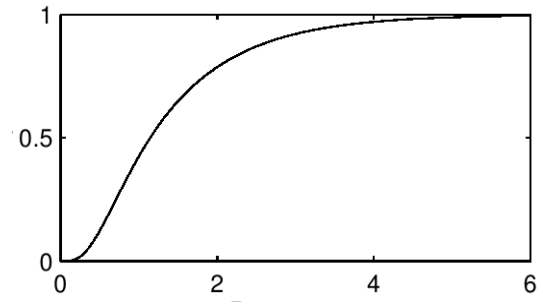
a)



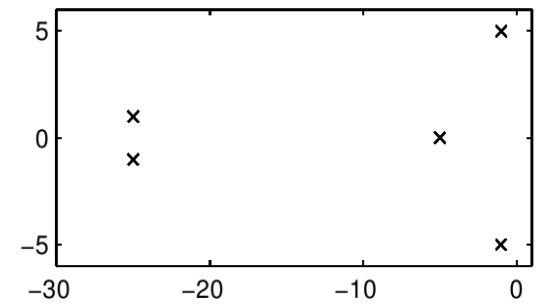
i)



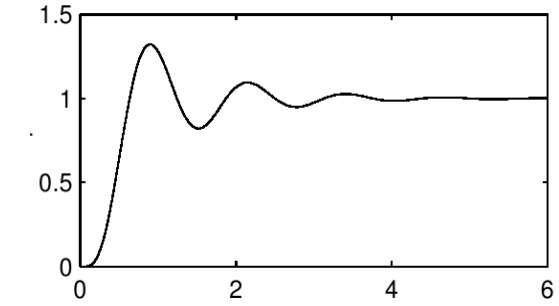
b)



ii)

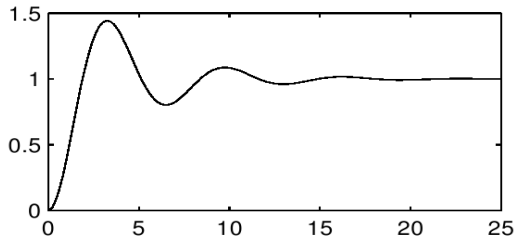
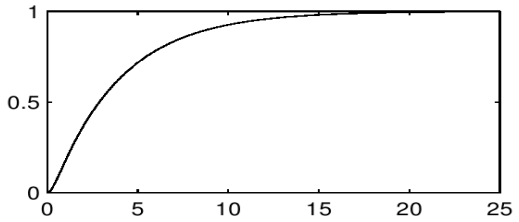
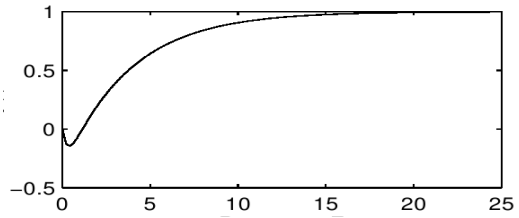
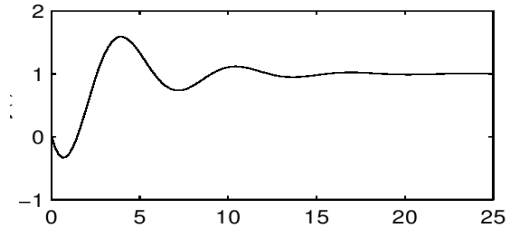
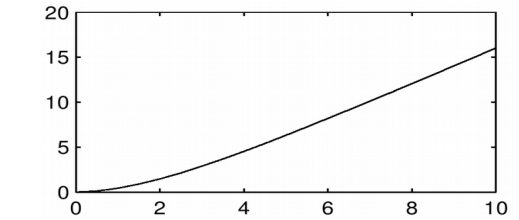
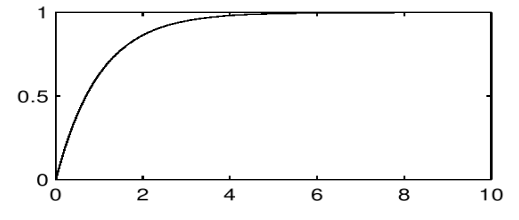


c)



iii)

b) (15 points) Associate the response to the transfer function

a) $G_1=\frac{1-s}{s^2+4s+1}$	 i)
b) $G_1=\frac{1}{s^2+0.5s+1}$	 ii)
c) $G_1=\frac{1}{s+1}$	 iii)
d) $G_1=\frac{1}{s^2+0.5s}$	 iv)
e) $G_1=\frac{1}{s^2+4s+1}$	 v)
f) $G_1=\frac{1-s}{s^2+0.5s+1}$	 vi)

Question 3 (25 points):

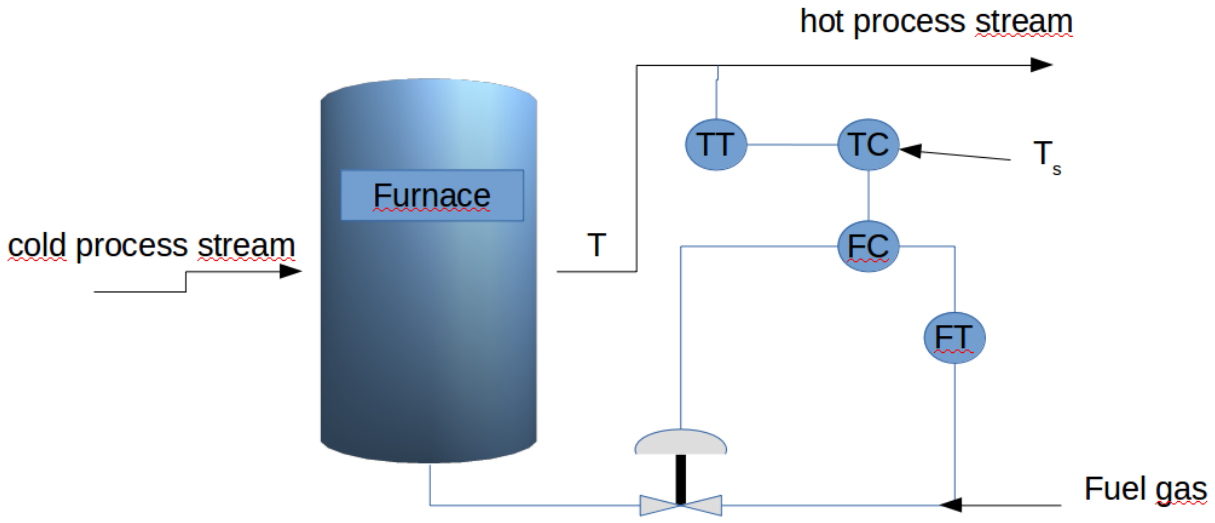
A first order dynamic process (Static gain 5, time constant 4) is to be controlled with a PI controller. In the control loop, all the systems have unit gains with negligible dynamics except for the measurement equipment which also has a static gain of 1 and a time constant of 1.

a) (10 points) Is the system closed-loop stable for a P only controller.

b) (15 points) What is the maximum value of the gain of a P only control to avoid overshoot of the closed-loop response ?

Question 4 (25 points):

The following process is to be controlled with a cascade loop where the temperature controller (TC) does not control directly the process but rather sends its signal to the flow control (FC) which will do the final control through the flow transducer (FT).



a) (10 points) The two disturbances in the system are in the cold process stream temperature and the fuel-gas pressure. The cascade control strategy is well-suited for the control of such a system. Draw the complete block diagram of the cascade control system, then reduce (close) the inner (or slave) loop to write a second block diagram as a standard feedback loop.

b) (15 points) The following values for the transfer functions of the furnace (P), the control valve (V) and the disturbance (fuel gas inlet pressure) (L) are known:

$$G_P = \frac{0.8}{2s+1} \quad , \quad G_v = \frac{0.5}{s+1} \quad , \quad G_L = \frac{0.75}{s+1} \quad .$$

The objective of the cascade control is to accelerate the response of the inner (or slave) loop, and thus to reduce the effect of this disturbance. Assuming that all the other equipment in the system have unit gain and instantaneous response, determine the proportionnal gain of the slave (P-only) controller K_{c2} to reduce the time constant of the slave loop to 1/10 of the original time constant of G_v .