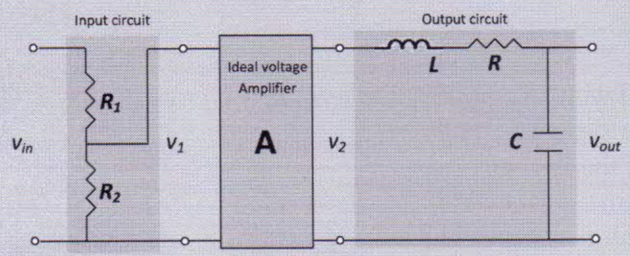
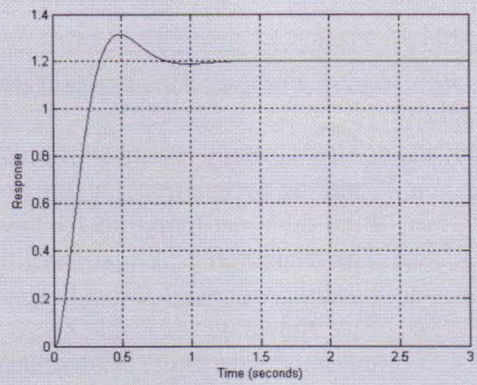
جامعة مصراتة	الامتحان النهائي	ربيع 2016/2015
كلية الهندسة	نظم تحكم 1	الاربعاء 2016/05/25
قسم الهندسة الكهربائية والالكترونية		الزمن: ثلاث ساعات

***Q1** (5 points)*. For the system of figure *(1-a)* with $R = 96\ \Omega$, $C = 1562.5\,\mu F$ and $L = 10\,H$.

a. Derive the transfer function of each block.
b. Find the overall transfer function of the system.
c. If the amplifier gain (A) is equal to *4* and the response of the system to a unit step is given in figure (*1-b*), and $R_2 = (150 - R_1)\ \Omega$, find the values of $\boldsymbol{R_1}$ and $\boldsymbol{R_2}$.
d. Find ω_n the undamped natural frequency of the overall circuit and ξ the damping ratio of the overall circuit.



(a)



(b)

Figure (*1*)

Q2 (*4 points*). For the control system shown in the block diagram of figure (*2*) :

a- What is the time constant of the process.

b- If the transfer function of the controller is $G_C(s) = \dfrac{K_I}{s}$ and $U(s) = \dfrac{1}{s}$, find the values of K_I to have a peak time $t_p = 2\,\text{sec}$ and a maximum overshoot $M_p = 15\%$.

c- What is the time constant of the overall system.

d- Find the transfer function that relates the output signal to the load *L(s)*.

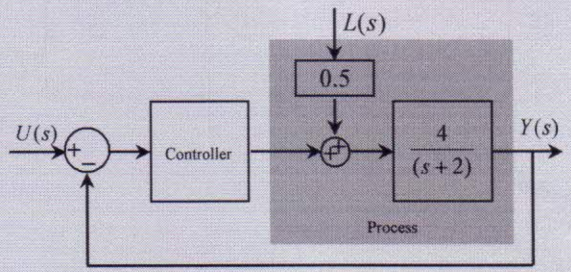


Figure (2)

***Q3** (5 points)*. Consider the system described by the block diagram of figure (*3*) with $G(s) = \dfrac{1}{s^2 + 2s + 7}$ and $H(s) = 2$.

(a) Find the overall transfer function of this system.
(b) If the input function is a unit step function, find :
- the rise time of the response signal.
- the peak time of the response signal.
- the maximum overshoot of the response signal
- the setting time for an allowable tolerance of 5%
- draw approximately the response of the system.

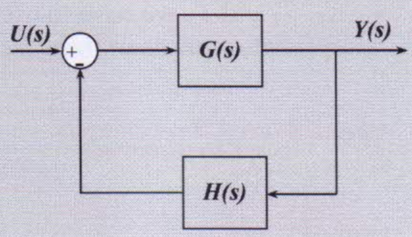


Figure (*3*)

Q4 *(3 points)*. For the system described by the block diagram of figure *(4)* find the overall all transfer function that relates the output signal *C(s)* to the input signal *R(s)*.

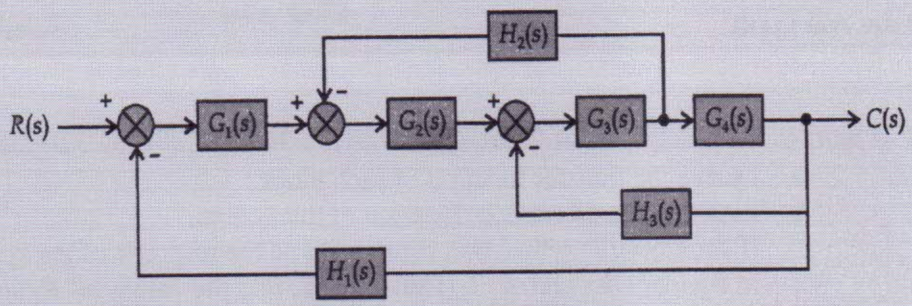


Figure *(4)*

Q5 *(8 points (6+2))*. For the control system of figure *(5-a)*:

1. If the control strategy is a proportional control with an amplification term *K*.
   a. Find the overall transfer function of the system.
   b. Find the open-loop transfer function of the system.
   c. The characteristic equation of the system.
   d. Find the values of *K* that keeps this control system stable.
   e. Find the values of *K* that keeps the roots of the characteristic equation of this system at the left hand side of the relative stability zone (refer to figure *(5-b)*).

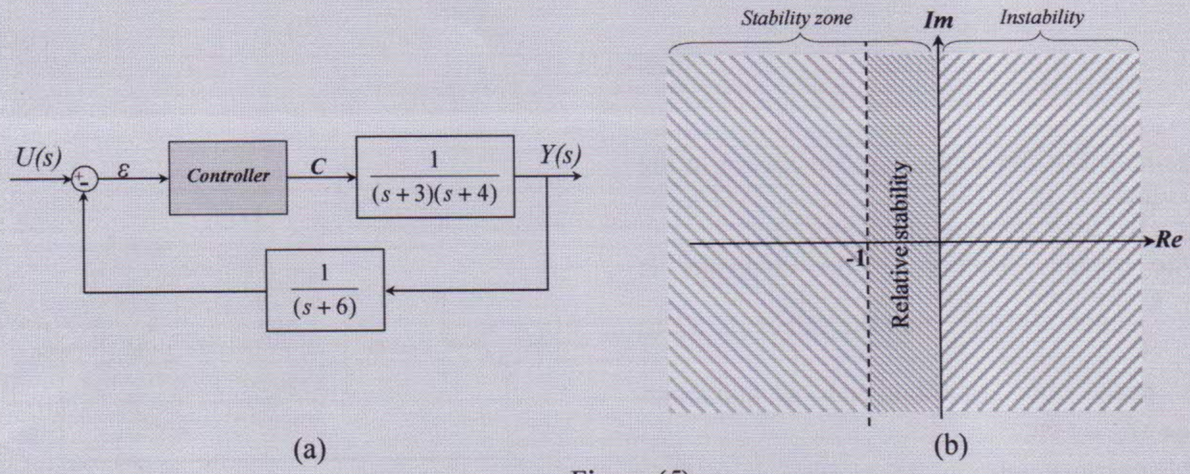


Figure *(5)*

2. If we want to use the PID controller schematized in figure *(6)*. Using the Ziegler-Nichols methods, what values of K_C, T_I and T_D we have to use to obtain an optimal response of the system.

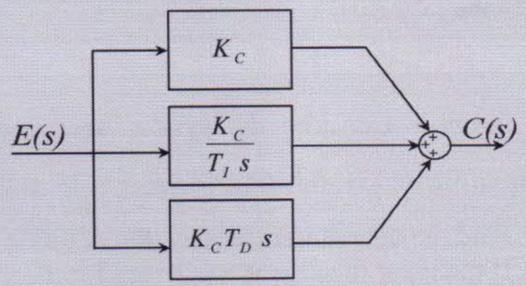


Figure *(6)*

☑ General form of the first order system: $G(s) = \dfrac{Y(s)}{U(s)} = \dfrac{1}{1+\tau s}$

☑ General form of the second order system: $G(s) = \dfrac{Y(s)}{U(s)} = \dfrac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2} = \dfrac{1}{\tau^2 s^2 + 2\xi\tau s + 1}$

Where ζ : is the system damping ratio,
$\omega_n = (1/\tau)$: is the system undamped natural frequency.

☑ The underdamped response case (for $\zeta < 1$) of the second order system to a unit step response can be characterized by:

1-Delay time (t_d). Is defined as the time required for the response to reach 50% from its ultimate value
2-Rise time (t_r). The time required for the response to first reach its ultimate value

$$t_r = \frac{\pi - \beta}{\omega_d} \quad \text{with } \beta = \tan^{-1}\left(\frac{\omega_d}{\xi\omega_n}\right) \quad \text{and } \omega_d = \omega_n\sqrt{1-\xi^2}$$

3-Peak time (t_p). The time required for the response to reach its peak $t_p = \dfrac{\pi}{\omega_d}$

4-Setting time (t_s): If the allowable tolerance is (2%) ⇨ $t_s = \dfrac{4}{\xi\omega_n}$

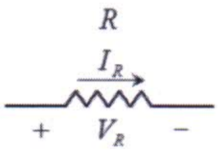
If the allowable tolerance is (5%) ⇨ $t_s = \dfrac{3}{\xi\omega_n}$

5- Maximum overshoot (M_p). Is the measure of how much the response exceeds the ultimate value following a step input $M_p = e^{\frac{-\pi\xi}{\sqrt{1-\xi^2}}}$.

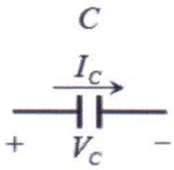
☑ PID controller Parameters (stability limits evaluation.)

Type of controller	**Optimum gain**
P	$K=0.5K_u$
PI	$K=0.45K_u$ $T_I=P_u/1.2$
PID	$K=0.6K_u$ $T_I=0.5P_u$ $T_D=P_u/8$

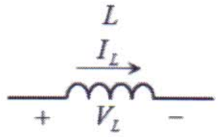
☑ Dynamic of basic electrical components :



$V_R(t) = RI_R(t)$
$I_R(t) = \frac{V_R(t)}{R}$



$V_C(t) = \frac{1}{C}\int_0^t I_C(\tau)d\tau$
$I_C(t) = C\frac{dV_C(t)}{dt}$



$V_L(t) = L\frac{dI_L(t)}{dt}$
$I_L(t) = \frac{1}{L}\int_0^t V_L(\tau)d\tau$

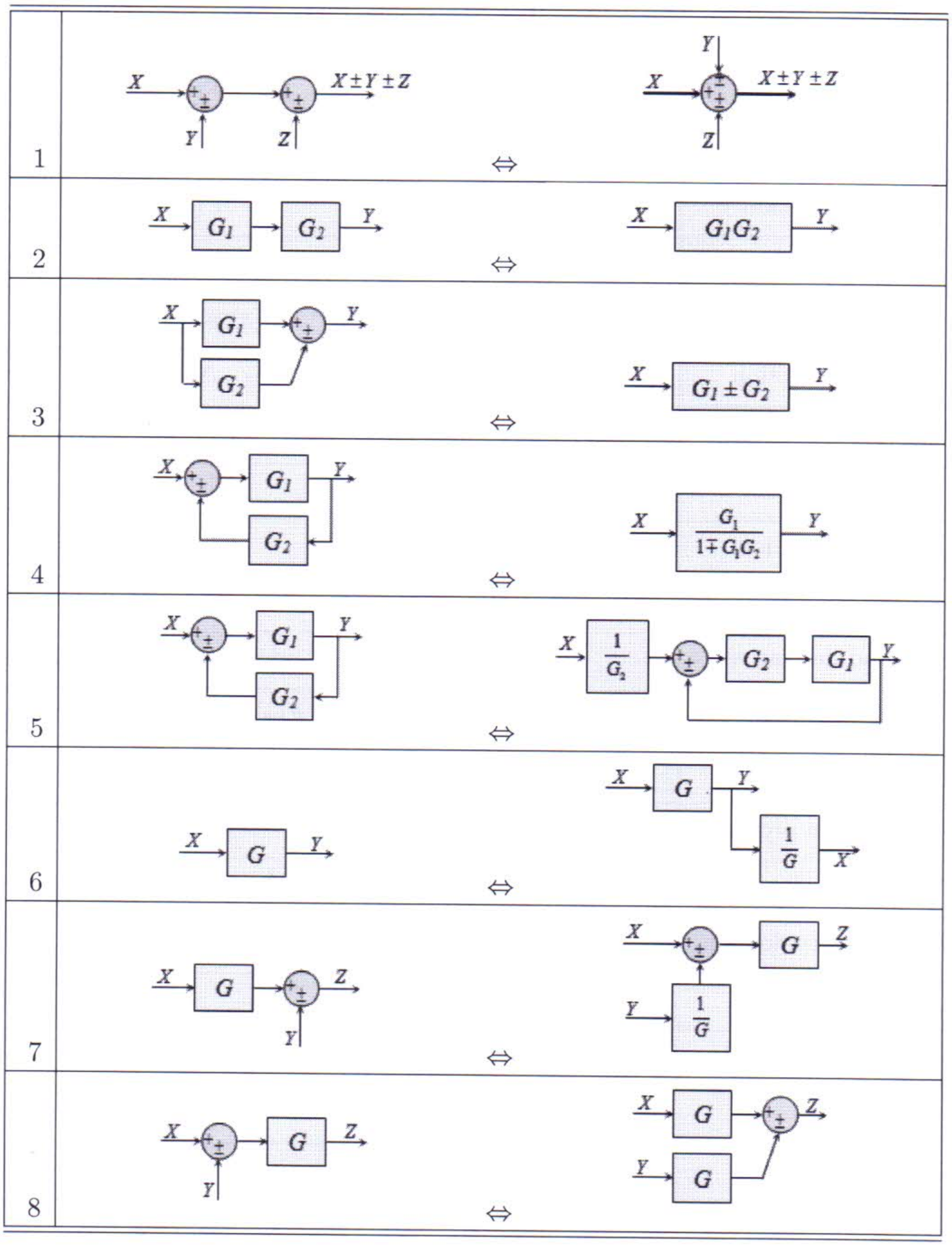


Table 6.1: System reduction basic operations.

Function	Time domain	Laplace domain
Unit step function	$u(t) = \begin{cases} 1 & t \geq 0 \\ 0 & t < 0 \end{cases}$	$U(s) = \frac{1}{s}$
Step function	$f(t) = Ku(t)$	$F(s) = \frac{K}{s}$
Ramp function	$f(t) = tu(t)$	$F(s) = \frac{1}{s^2}$
Ramp function	$f(t) = t^2u(t)$	$F(s) = \frac{2}{s^3}$
Ramp function	$f(t) = t^nu(t)$	$F(s) = \frac{n!}{s^{n+1}}$
Pulse function	$f(t) = K(u(t) - u(t - t_1))$	$F(s) = \frac{K}{s}(1 - e^{-st_1})$
Impulse function	$\delta(t)$	$\Delta(s) = 1$
Exponential function	$f(t) = Ke^{-at}\ u(t)$	$F(s) = \frac{K}{(s+a)}$
Sine function	$f(t) = A\ sin(\omega t)\ \ u(t)$	$F(s) = \frac{A\omega}{s^2+\omega^2}$
Cosine function	$f(t) = A\ cos(\omega t)\ \ u(t)$	$F(s) = \frac{As}{s^2+\omega^2}$
First derivative	$\dot{f}(t)$	$sF(s) - f(0)$
Second derivative	$\ddot{f}(t)$	$s^2F(s) - sf(0) - \dot{f}(0)$
n^{th} derivative	$f^n(t)$	$s^nF(s) - \sum_{k=1}^{n} s^{k-1}f^{(n-k)}(0)$
Integration	$\int_0^t f(\tau)d\tau$	$\frac{1}{s}F(s)$
Convolution product	$\int_0^t f(\tau)g(t-\tau)d\tau$	$F(s)G(s)$
Shift (time domain)	$f(t - a)$	$e^{-as}F(s)$
Shift (Laplace domain)	$e^{at}f(t)$	$F(s - a)$
Multiplying by t	$tf(t)$	$-\acute{F}(s)$
Multiplying by t^n	$t^nf(t)$	$(-1)^nF^{(n)}(s)$
	t^ne^{at}	$\frac{n!}{(s-a)^{n+1}}$
	$f(at)$	$\frac{1}{\lvert a\rvert}F(\frac{s}{a})$
Hyperbolic sine	$sinh(\omega t)$	$\frac{\omega}{s^2-\omega^2}$
Hyperbolic cosine	$cosh(\omega t)$	$\frac{s}{s^2-\omega^2}$

Table 3.1: Summary of Laplace transform.