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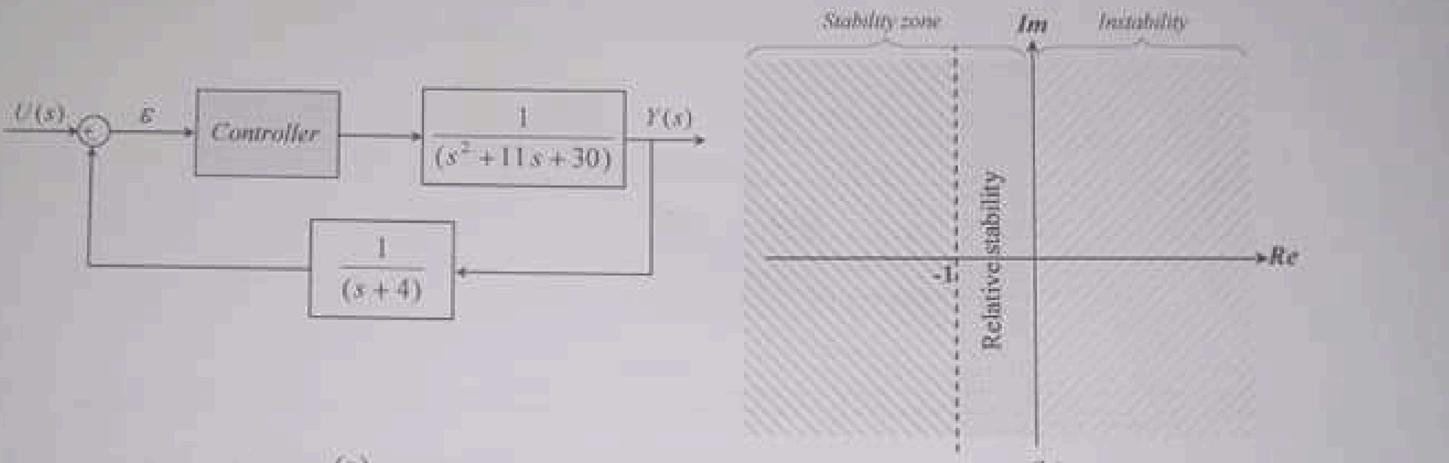
الزمن: ساعتان ونصف	نظم تحكم 1	قسم الهندسة الكهربائية والالكترونية

Q1 (10 points). For the control system of figure *(1-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 stable this control system.
   e. Find the values of *K* that keeps the roots of the characteristic equation of this system out of the relative stability zone (refer to figure (*1-b*)).



(a) (b)

Figure (*1*)

2. If we want to use the PID controller schematized in figure (*2*). 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.

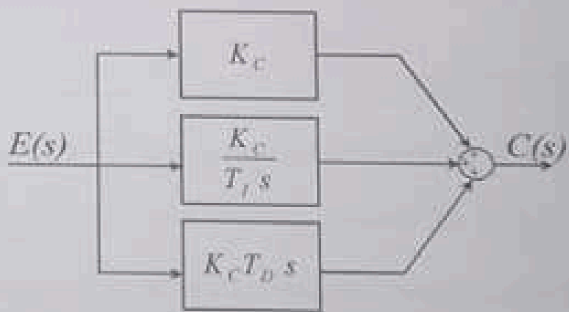


Figure (*2*)

Q2 (*10 points*). For the system described by the block diagram of figure (*3*), with $G_1(s)=3$, $G_2(s)=\frac{1}{(s+2)}$, $G_3(s)=(s+1)$, $G_4(s)=\frac{1}{(s+1)}$, $H_1(s)=\frac{1}{(s+3)}$, $H_2(s)=\frac{1}{(s+1)}$, and $H_3(s)=1$. Find the overall transfer function of the system.

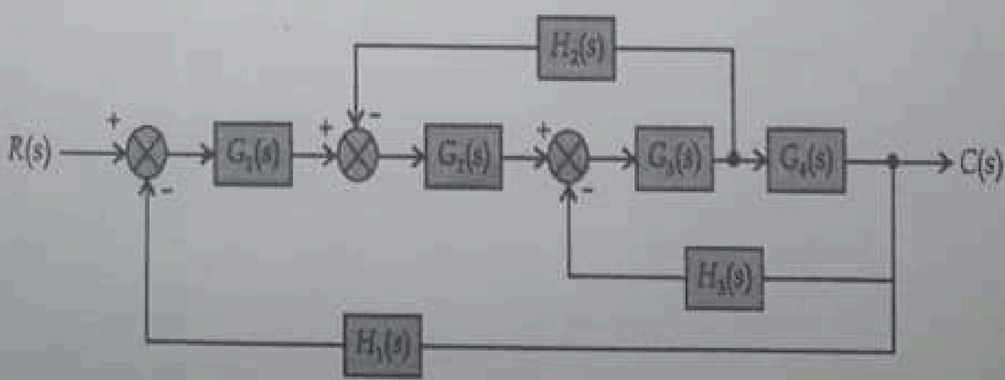


Figure (*3*)

Q3 *(10 points)*. Consider the cascaded liquid storage tanks shown in figure (4). The differential equation describing the behaviour of the first tank is given as $h_1'(t) = 8\,(F_{in}(t) - F_{12}(t))$ and the differential equation describing the behaviour of second tank is given as $h_2'(t) = 10(F_{12}(t) - F_{out}(t))$. The first tank output flow rate is given as $F_{12}(t) = 0.0625\,h_1(t)$ and the second tank output flow rate is given as $F_{out}(t) = 0.05 h_2(t)$. Assuming that the two tanks were empty at initial time, find the following:

(a) The transfer function that relates h_1 to F_{in}.
(b) The transfer function that relates h_2 to F_{12}.
(c) The transfer function that relates h_2 to F_{in}.
(d) find $h_2(t)$, If $F_{in}(t)$ is a unit step signal.
(e) The time constant of the first tank, and the time constant of the dynamic between $h_2(t)$ and $F_{in}(t)$.

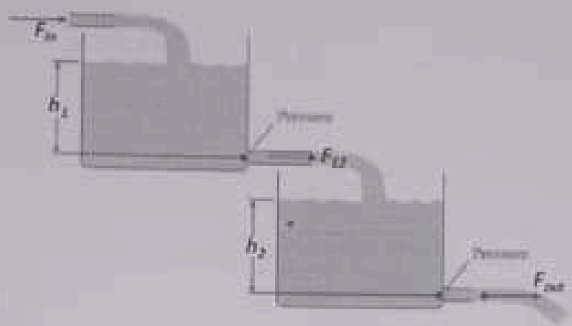


Figure (4)

Q4 *(10 points)*. Plot Bode diagram for the open loop system configured in figure (5) with $G(s) = \dfrac{250\,(s+0.04)}{(s+10)(s+1)(s+0.01)}$. Find also the gain and the phase margins for this system.

Figure (5)

Q5 *(10 points)*. For the system of figure (6-a) the forcing function F is a step input of 2 Newton. Knowing that the transfer function of the system is $\dfrac{X(s)}{F(s)} = \dfrac{1}{ms^2 + bs + k}$ where and m is the mass of the body, k is the spring constant and b is the friction coefficient. If the response of the system was the function given in figure (6-b) find the values of m, b and k.

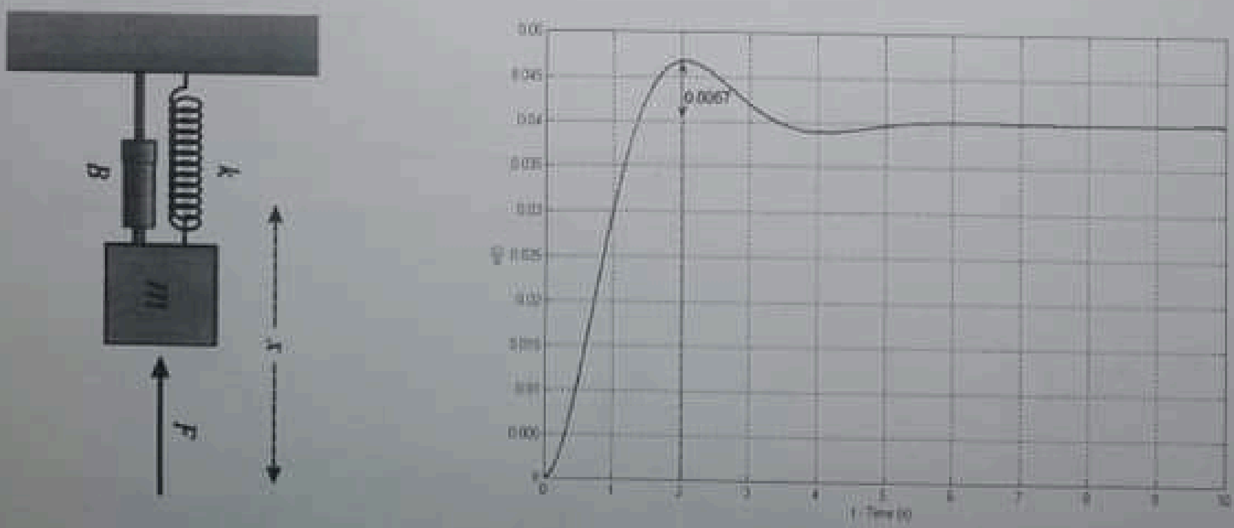


Figure (6-a)

Figure (6-b)

Figure (6)

ω	Φ
0.001	-4.34
0.002	-8.57
0.003	-12.60
0.005	-19.76
0.008	-27.85
0.01	-31.59
0.02	-38.13
0.03	-36.59
0.05	-30.50
0.08	-24.47
0.1	-22.37
0.2	-20.90
0.3	-24.10
0.5	-32.86
0.8	-45.38
1	-52.43
2	-75.60
3	-88.84
5	-105.60
8	-121.75
10	-129.46
20	-150.66
30	-159.71
50	-167.58
80	-172.18
100	-173.73
200	-176.86
300	-177.91
500	-178.74
800	-179.21
1000	-179.37

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

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

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 $t_p=\frac{\pi}{\omega_d}$

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

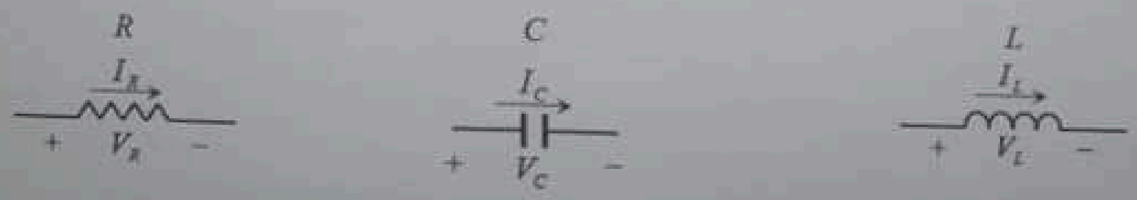
If the allowable tolerance is (5%) ⇨ $t_s=\frac{3}{\xi\omega_n}$

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 :



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

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

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