



TECHNICAL UNIVERSITY OF MOMBASA

Faculty of Engineering and Technology
Department of Mechanical & Automotive Engineering
UNIVERSITY EXAMINATION FOR:
BSc. Mechanical Engineering
EMG 2405 : Control Engineering I
END OF SEMESTER EXAMINATION
SERIES: APRIL 2016
TIME: 2 HOURS
DATE: Pick Date Apr 2016

Instruction to Candidates:

You should have the following for this examination

- Answer booklet
- Non-Programmable scientific calculator

This paper consists of **FIVE** questions. Attempt question **ONE** and any other **TWO** questions.

Maximum marks for each part of a question are as shown.

Do not write on the question paper.

Question ONE (Compulsory)

- a. Figure Q1a shows a process which is being controlled in a closed-loop system with unity feedback. The process can be modelled using a first-order model with system gain, K , and a system time constant, τ . (15 marks)

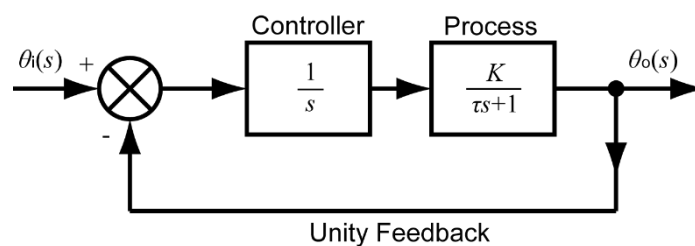


Figure Q1a

- Obtain the expression for the forward-path transfer function for the system, $G_o(s)$.
- Determine the system type number.
- Obtain the expression for the closed-loop transfer function for the system, $G(s)$.
- If this system was subject to a unit step reference input, what would be the steady-state error value? Use your knowledge of system types, controller effects or the final value theorem.

- v. If the system time constant, τ is 0.1 seconds and the system gain K is 2.5, will the closed-loop system be underdamped, critically damped or over-damped?
- b. Consider the closed loop system with a unity feedback as shown in Figure Q1b.

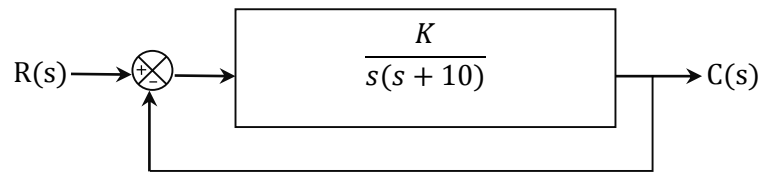


Figure Q1b

- i. Determine the gain K so that the system will have a damping ratio of 0.5.
- ii. For the obtained value of K determine the following for a unit step input:
 - i. Settling time,
 - ii. Rise time,
 - iii. Time to peak,
 - iv. Maximum overshoot (15 marks)

Question TWO

- a. State any TWO advantages of modern control approach to system modeling as compared to classical approach. (2 marks)
- b. Define the following terms:
 - i. State vector,
 - ii. State variable, (2 marks)
- c. Consider a transfer function of a system as shown in Figure Q2a

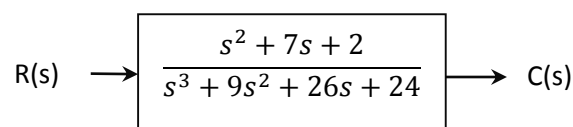


Figure Q2a

- i. Find the state equation and output equation for the phase variable representation of the transfer function.
- ii. Draw an equivalent block diagram showing phase variables. (10 marks)
- d. Figure Q2b shows the translational mechanical system. Obtain the state model of the system. (6 marks)

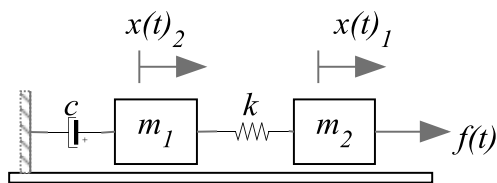


Figure Q2b

Question THREE

- a.
- i. State Routh-Hurwitz criteria for stability. (3 marks)
 - ii. State any THREE limitations of using Hurwitz criteria for determining stability of a system. (6 marks)
 - iii. Consider the closed loop system shown in Figure Q3a. Determine the range of values of K for which the system is stable. (6 marks)

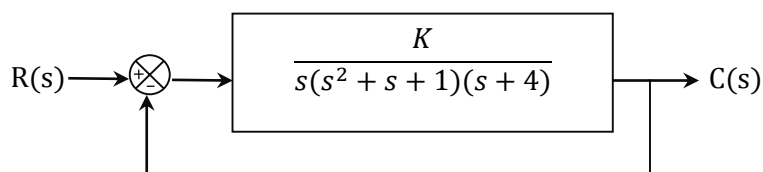


Figure Q3a

- b. Figure Q3(b) shows the block diagram for a system which has two subsystem blocks on the feed-forward path and two subsystem blocks on the negative feedback path. Derive an expression for the output response $\theta_o(s)$ in terms of the reference input $\theta_i(s)$ and the two disturbance inputs $\theta_{d1}(s)$ and $\theta_{d2}(s)$. (5 marks)

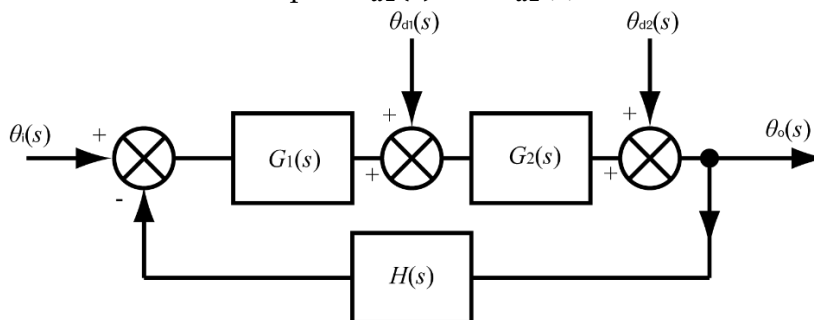


Figure Q3b

Question FOUR

Figure Q4 shows the block diagram of a complex system which includes three negative feedback loops, the outermost of which is a unity feedback loop.

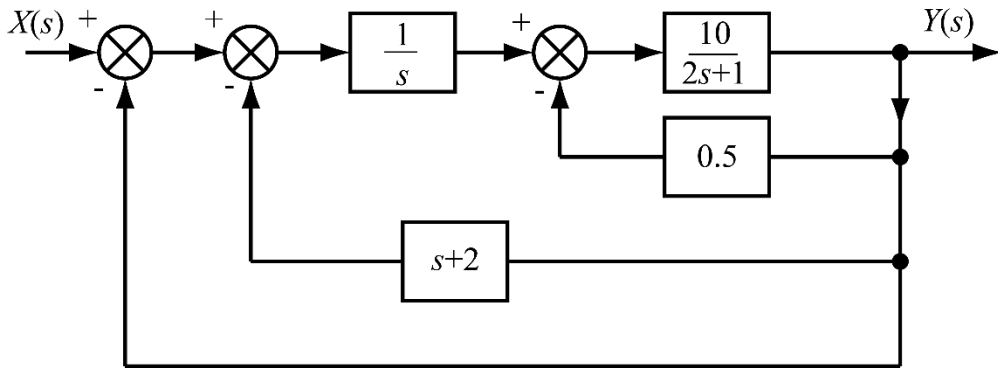


Figure Q4

a. Show whether the above closed-loop system is stable or unstable. **(8 marks)**

b. Either through knowledge of the response of system types to different inputs or by applying the final value theorem calculate the steady-state error for this system to the following inputs:

- i. A step input of magnitude 10.
- ii. A ramp input given by $x(t) = 10t$.
- iii. A parabolic input given by $x(t) = 10t^2$ **(6 marks)**

c. Calculate an expression for the output time response of the system $y(t)$ when the input is a step input of magnitude 10 if the output response is zero at time $t = 0$. **(6 marks)**

Question FIVE

a. State the effect of introducing feedback on the stability of control systems. **(2 marks)**

b.

- i. State the Nyquist criterion.
- ii. The Nyquist plot of a unity feedback system having open loop transfer function is as shown in Figure Q5a.

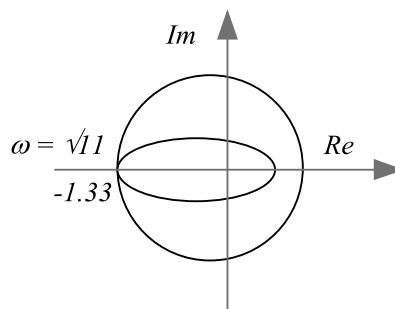


Figure Q5a.

Given the open loop transfer function:

$$G(s) = \frac{K(s+5)(s+3)}{(s-2)(s-4)}$$

When $K=1$ the system is stable. Determine the range of K for the system to be considered stable. **(8marks)**

- c. Figure Q5b shows a schematic of an armature-controlled d.c. motor which essentially consists of an armature coil in a magnetic field. The armature consists of a resistance, R , and an inductance, L , in series. When current, i , flows through the armature, the coil rotates generating a torque, T , which is proportional to the current, so that $T = K_m i$. Since the armature is rotating in a magnetic field, a voltage, known as the back e.m.f. (e) will be induced in it. The back e.m.f. is proportional to the armature rotation speed, ω , so that $e = K_b \omega$. The motor drives a mechanical load with moment of inertia, I , and with a rotary viscous damping coefficient, c .

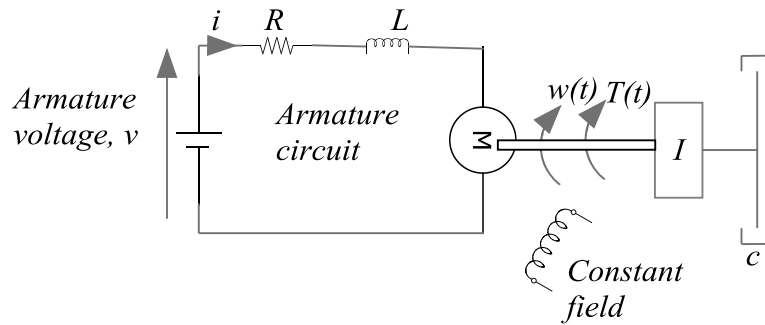


Figure Q5b

Show that the transfer function which relates $\Omega(s)$, the Laplace transform of the armature rotation speed, $\omega(t)$, to $V(s)$, the Laplace transform of the armature voltage, $v(t)$, is given by the following expression: **(10 marks)**

$$G(s) = \frac{\Omega(s)}{V(s)} = \frac{K_m}{(LIs^2 + (RI + cL)s + (Rc + K_b K_m))}$$

