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: 15 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. Draw a block-diagram of a typical negative-feedback, closed-loop system, labelling the individual blocks and the system inputs and outputs. State two advantages and two disadvantages of closed-loop systems when compared to open-loop systems. **(6 marks)**

b. Find the unit step response of a unity-feedback control system whose open-loop transfer function is given as,

$$G_O(s) = \frac{144}{s(s+12)}$$

And also obtain,

i. Delay time t_d
ii. Rise time t_r
iii. Peak time t_p
iv. Maximum overshoot M_p
v. Settling time t_s (for 2%) **(15 marks)**

c. Consider the closed loop system with a unity feedback system as shown in Figure Q1a. Determine the value of gain K so that the system will have a damping ratio of 0.5.

(4 marks)

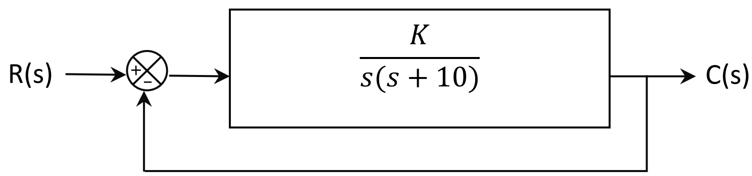

Figure Q1a

d. It is found that the behavior of many mechanical systems can be adequately represented as a single-degree-of-freedom system as shown in Figure Q1b. The mass of the system is m kg, the linear spring stiffness is k N/m and the damping coefficient is c N/(m/s).

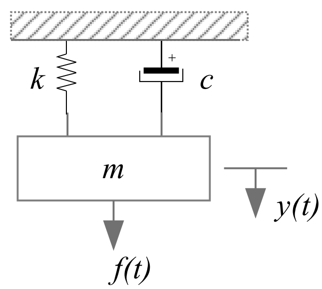

Figure Q1b

i. Draw a free body diagram of the system and derive an expression for the relationship between the output displacement, $y(t)$, and the input force, $f(t)$.

ii. Write an expression for the transfer function $G(s)$ which relates the output response $Y(s)$, the Laplace transform of $y(t)$, to the input $F(s)$, the Laplace transform of $f(t)$. Assume that the initial displacement and velocity are both equal to zero. **(5 marks)**

Question TWO

a. Consider a transfer function of a system as shown in Figure Q3a

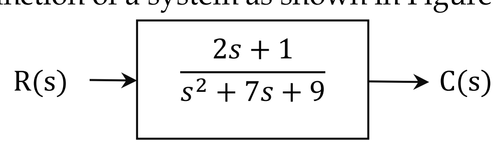

Figure Q3a

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)**

b. Consider an RLC network as shown in Figure Q3b. Determine,

i. The transfer function $G(s) = V_2(s)/V_1(s)$, of the system.

ii. The state space model of the RLC network. **(10 marks)**

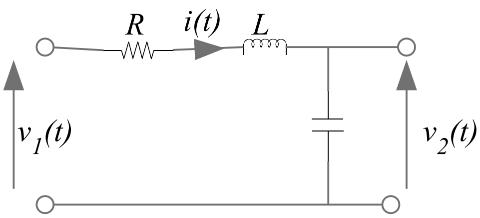

Figure Q3b

Question THREE

a. State Routh-Hurwitz criteria for stability.

b. Define the terms:

  i. Stable.

  ii. Limitedly stable.

  iii. Unstable. **(6 marks)**

c. Consider the closed loop system shown in Figure Q3a. Determine the range of values of K for which the system is stable. **(8 marks)**

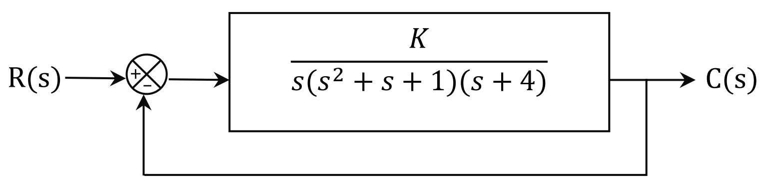

Figure Q3a

d. Find the equivalent transfer function, $T(s) = C(s)/R(s)$, for the system shown in Figure Q3b. **(6 marks)**

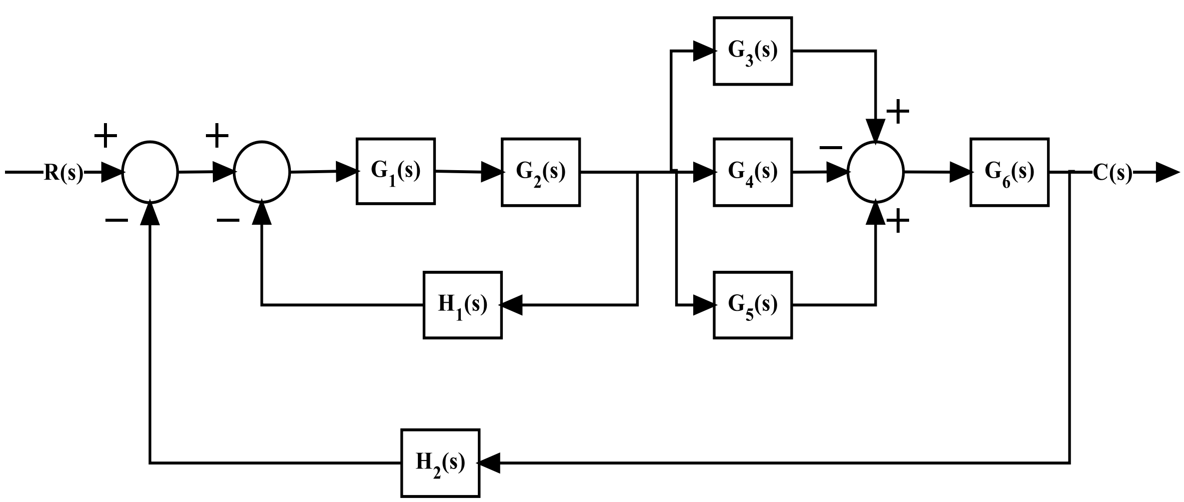

Figure Q3b

Question FOUR

a. Consider a rotational mass-spring-damper system as shown in figure Q4a. Find the values of ***J*** and ***c*** to yield a response with 20% overshoot and a settling time of 2 seconds for a unit step input of torque *T(t)*. Given k = 5Nm/rad **(10 marks)**

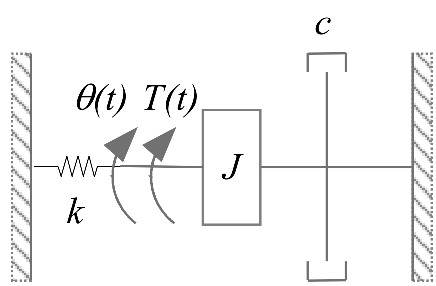

Figure Q4a

b. Figure Q4b 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 $e = K_b$ ω. The motor drives a mechanical load with moment of inertia, *I*, and with a rotary viscous damping coefficient, *c*.

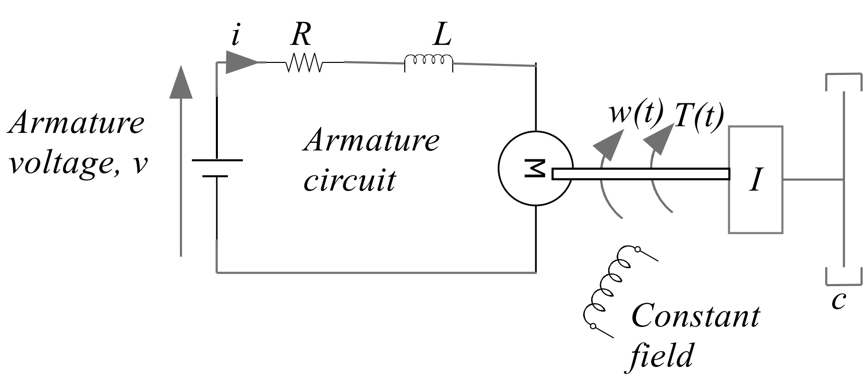

Figure Q4b

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)**

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

Question FIVE

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

   i. State the Nyquist criterion.
   ii. Explain how the stability of a control system may be determined from a Nyquist plot.
   iii. State the disadvantages of the Nyquist plot over the Bode plot.

(9 marks)

b. A control system has an open loop transfer function

$$G(s) = \frac{14}{(s+1)(s+2)}$$

Determine,

i. Resonant frequency, w_r.
ii. Resonant peak, M_r.
iii. Deduce whether the system is stable or not. **(9 marks)**