Major Examination Question Paper on Control Theory and Applications (MCL212) May 2018

This paper contains two parts, Part-I, for 30 marks and Part-II for 15 marks.

Answer all the questions.

The part-II has 15 questions of 1 mark each and these are to be answered on the question paper, which should be returned. There is one correct answer. You will lose ½ mark for each wrong answer.

Full Marks: 45

Time: 2 hours.

Problem-1: Modelling of Systems

The figure-1 is that of a hydraulic tank valve system where the tank has two outlets one at the bottom and the other at the top. The bottom outlet is situated at the datum level and is referred to by marking with subscript 'B'. The top outlet, referred to by marking with subscript 'T', is situated at a distance d over the bottom, as shown in the figure. Suppose that in the steady state the head of water in the tank is H meter from the datum, as shown. Suppose R_T and R_B are the resistances of the top and bottom outlet valves and 'C' is the constant capacitance of the tank. During the steady state, the input pipe over the tank supplies water at a rate of $\bar{Q}_{in}$ m³/sec. and the output rates through the top and bottom outlets are $\bar{Q}_{OT}$ and $\bar{Q}_{OB}$ m³/sec. respectively.

(a) At this situation there is a fluctuation in the input flow rate given by $q_{in}(t)$ m³/sec about the steady in-flow rate and correspondingly there is a fluctuation of the head of the water in the tank by h(t) about the steady head H. Draw a block diagram to represent the dynamic behaviour of fluctuation of the head of water in the tank as the output of the block diagram, when the fluctuation of water in-flow rate is considered as the input. (3)

(b) For the system, find from the above block diagram, the transfer function $H(s)/Q_i(s)$, i.e. the fluctuation of the head of water in the tank due to fluctuation of the input flow rate. (2)

(c) Draw an equivalent electrical circuit to represent the same dynamic hydraulic behaviour in the electrical domain, i.e. the same transfer function between the output and input, by using only resistance and capacitance elements. Mention the input and the output in the electrical system. (3)

(d) In a hydraulic system as described in the problem, the rate of discharge through an outlet 'qo' in general is given by $q_o = K*\sqrt{H_o}$, where H_o is the head of water the outlet is subject to and $K = C_D A_o \sqrt{2g}$, where C_D is the coefficient of discharge, A_o is the area of cross-section of the outlet and 'g' is the acceleration due to gravity the value of which may be taken to be 9.81 m/sec². From the expression of q_o in terms of H_o given above, calculate the resistance R_T and R_B of the top and bottom outlet valves. Suppose that $C_{DT} = 0.4$, $C_{DB} = 0.5$, diameter of the top and bottom outlets as 0.01 meter and 0.02 meter and the head of water as 2.5 meter and 5 meter over top and bottom outlets respectively. Also write their units. (2)

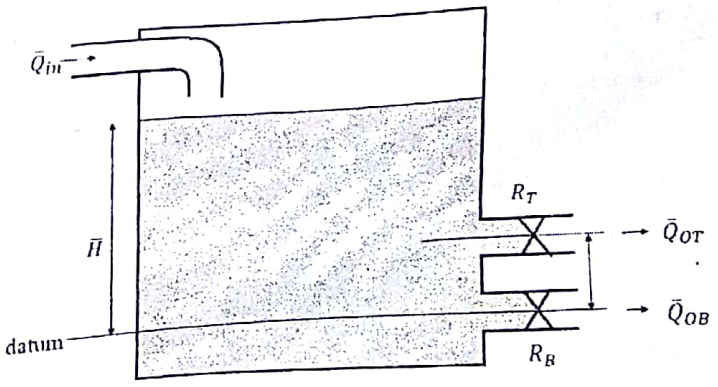

Figure 1

P.T.O.

Problem-2: Control System Design

Asymptotic approximation of magnitude of a Bode plot of the open loop transfer function of a system is shown in figure-2. The closed loop system has unity feedback.

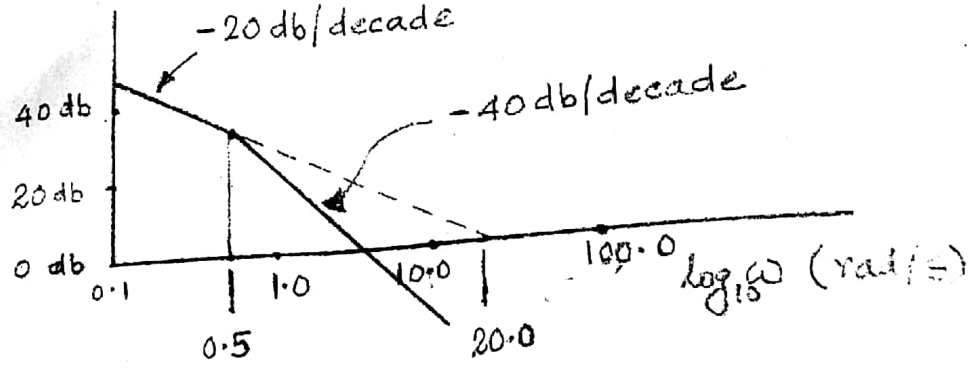

Figure 2

(a) From figure-2 extract the open loop transfer function G(s). Also derive the expression of the closed loop transfer function. (2+1)

(b) It is desired that the closed loop system should have a natural frequency ω_n of 7 radian/second, a damping factor ζ of 0.5 and steady state velocity error constant ≥ 70. Design suitable compensators to achieve the specified conditions and write the compensated open-loop transfer function $G_{com}(s)$. (4+4)

(c) Find the value of steady state velocity error constant after compensation and show that this is ≥ 70. (1)

Problem-3: Sequence control

Assume a traffic signal with three lights. The sequence of the lights is as follows: RED (2 minutes) > AMBER (5 seconds) > GREEN (2 minutes) > AMBER (5 seconds)> repeat. The system may be started by a push switch (S1).

An emergency stopping sequence is built into the system. Whenever a sensor (S2) detects a person on the road when the signal state is either GREEN or AMBER, the system resets itself to RED light and then follows the usual sequence.

A manual emergency push button is also there to reset the system to RED light.

(4+2+2=8)

Design a ladder diagram implementing the sequence.