[ESS05]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BENG (HONS) IN MECHANICAL ENGINEERING

SEMESTER TWO EXAMINATION 2018/2019

THERMOFLUIDS & CONTROL SYSTEMS

MODULE NO: AME5013

Date: Tuesday 21st May 2019 **Time: 10:00 – 12:00**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions on this paper.

Answer ANY FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

CANDIDATES REQUIRE :

Property Tables provided
Formula sheet (attached)
Take density of water as 1000 kg/m^3

Q1 a) Define the following:

i) Discharge
ii) Mass flow rate
iii) Steady flow
iv) Adiabatic process

(10 marks)

b) Water with density 1000 kg/m^3 flows in a pipe. At a section where the inside diameter is 150 mm, the velocity is 3 m/s and the pressure is 350 kPa. At a section, located 10 m from the first section the inside diameter reduced to 75 mm. Calculate the pressure at the second section if:

i) The pipe is horizontal **(7 marks)**
ii) The pipe is vertical and the flow is downward **(8 marks)**

Take height as 10 m

Total 25 marks

Q2 a) Describe with the aid of a diagram the principles of operation of the Pitot and Pitot static tubes meter. **(10 marks)**

b) A venturi meter having a throat diameter d_2 of 100 mm is fitted into a pipeline which has a diameter d_1 of 250 mm through which oil of specific gravity 0.9 is flowing. The pressure difference between the entry and throat is measured by a U-tube manometer containing mercury of specific gravity 13.6 and the connections are filled with the oil flowing in the pipeline. If the difference of level indicated by the mercury in the U-tube is 0.63m calculate the theoretical volume rate of flow through the meter.

. **(15 marks)**

Total 25 marks

Q3 a) During some actual expansion and compression processes in piston cylinder devices, the fluids have been observed to satisfy the relationship $PV^n = C$

Calculate the work done when a fluid expands from a state of 100 kPa and $0.05 m^3$ and final volume $0.3\ m^3$ for the case when n=1.2.

(10 marks)

b) A jet of water 12.5 mm in diameter has a velocity of 15 m/s it strikes a plate moving in the same direction as the jet with a velocity of 3 m/s. Determine the force exerted by the jet on the plate. What will be the force on the plate if the velocity of the plate is increased to 12 m/s.

(15 marks)

Total 25 marks

Q4 Figure Q4 shows a simplified mechanical system, where

M = 10 Kg; K_1 = 2 N/m; K_2 = 4 N/m; C = 3 Ns/m

(a) Develop the differential equations for the variables y1 and y2 of the mechanical system. **(8 marks)**

(b) Determine the Laplace transforms of the differential equations obtained from Q4(a) above. Assume that the system is subjected to a unit step input and the initial conditions of the system are zeros (i.e. at time = 0, x, x', x'' are all zeros). **(4 marks)**

(c) Determine the transfer function G(s) = Y2(s)/F(s) **(8 marks)**

(d) Explain the differences between open-loop and closed-loop control systems.

(5 marks)

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Q4 continued ….

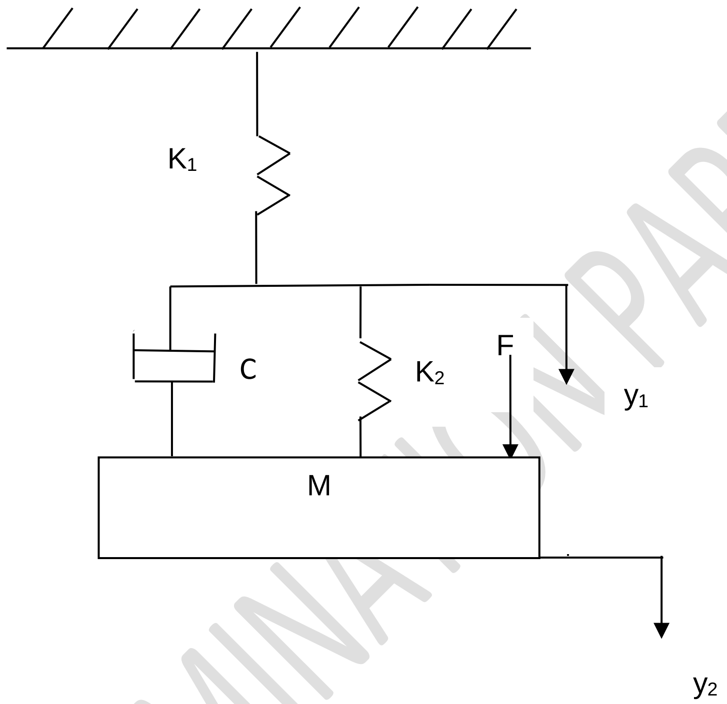

Figure Q4 A Simplified Mechanical System

Total 25 marks

Q5 (a) A vehicle system has a time constant of 0.15 seconds. If it's speed is suddenly increased from being at 30 KM/Hour into 100 KM/Hour,

(i) What will be the speed indicated by the speedometer after 0.3 seconds? **(4 marks)**

(ii) If the maximum speed of the vehicle is 150 KM/Hour and a unit step inputs into the system, determine the time t taken for the speed output of the system from 0 KM/Hour to reach 80% of its maximum speed value. **(6 marks)**

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Q5 continued…

(b) Figure Q5 shows a block diagram for a hydraulic control system.

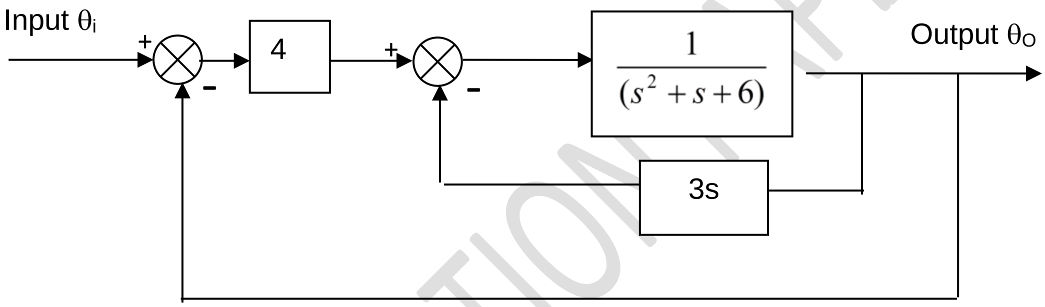

Figure Q5 A Hydraulic Control System

(i) What is the hydraulic system's transfer function G(s) = θ_o/θ_i?

(5 marks)

(ii) If a unit step input is applied into the system, determine the system's percentage overshoot, rise time, settling time, peak time, natural frequency, damped frequency, and damping ratio.

(10 marks)

Total 25 marks

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Q6 If a position control system has experienced a disturbance D(s), and a gain K has been inserted into the system as shown in Figure Q6:

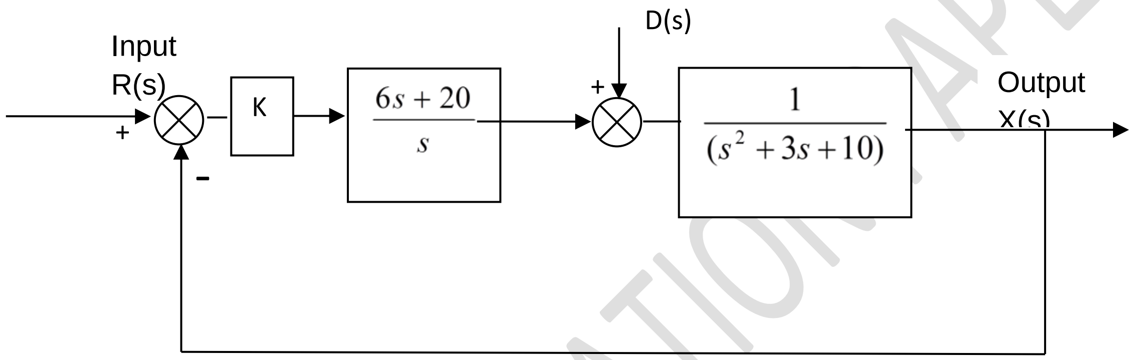

Figure Q6 Position control system

Determine

(a) the whole system's output θ_o(s) function **(8 marks)**

(b) the range of values of K for the system which will result in stability, using Routh-Hurwitz stability criterion.

(10 marks)

(c) the steady-state error if the disturbance D(s) = 0, R(s) is a unit ramp input, and K = 2;

(7 marks)

Total 25 marks

END OF QUESTIONS

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FORMULAE SHEETS

Blocks with feedback loop

G(s) = $\frac{Go(s)}{1+Go(s)H(s)}$ (for a negative feedback)

G(s) = $\frac{Go(s)}{1-Go(s)H(s)}$ (for a positive feedback)

Steady-State Errors

$e_{ss} = \lim_{s\to 0}[s(1-G_O(s))\theta_i(s)]$ (for an open-loop system)

$e_{ss} = \lim_{s\to 0}[s\frac{1}{1+G_o(s)}\theta_i(s)]$ (for the closed-loop system with a unity feedback)

$e_{ss} = \lim_{s\to 0}[s\frac{1}{1+\frac{G_1(s)}{1+G_1(s)[H(s)-1]}}\theta_i(s)]$ (if the feedback H(s) ≠ 1)

$e_{ss} = \lim_{s\to 0}[-s\cdot\frac{G_2(s)}{1+G_2(G_1(s)+1)}\cdot\theta_d]$ (if the system subjects to a disturbance input)

Laplace Transforms

A unit impulse function 1

A unit step function $\frac{1}{s}$

A unit ramp function $\frac{1}{s^2}$

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First-order systems

$$G(s) = \frac{\theta_o}{\theta_i} = \frac{G_{ss}(s)}{\tau s + 1}$$

$$\tau\left(\frac{d\theta_o}{dt}\right) + \theta_o = G_{ss}\theta_i$$

$$\theta_O = G_{ss}(1 - e^{-t/\tau})$$ (for a unit step input)

$$\theta_o(t) = G_{ss}[t - \tau(1 - e^{-(t/\tau)})]$$ (for a ramp input)

$$\theta_o(t) = G_{ss}(\frac{1}{\tau})e^{-(t/\tau)}$$ (for an impulse input)

Second-order systems

$$\frac{d^2\theta_o}{dt^2} + 2\zeta\omega_n\frac{d\theta_o}{dt} + \omega_n^2\theta_o = b_o\omega_n^2\theta_i$$

$$G(s) = \frac{\theta_o(s)}{\theta_i(s)} = \frac{b_o\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$t_r = \frac{(\frac{1}{2})\pi}{\omega_d}$

$t_p = \pi/\omega_d$

$t_s = 4/(\zeta\omega_n)$

$\omega_d = \omega_n\sqrt{(1-\zeta^2)}$

Percentage overshoot (PO) = $e^{\left(\frac{-\zeta\pi}{\sqrt{(1-\zeta^2)}}\right)} \times 100\%$

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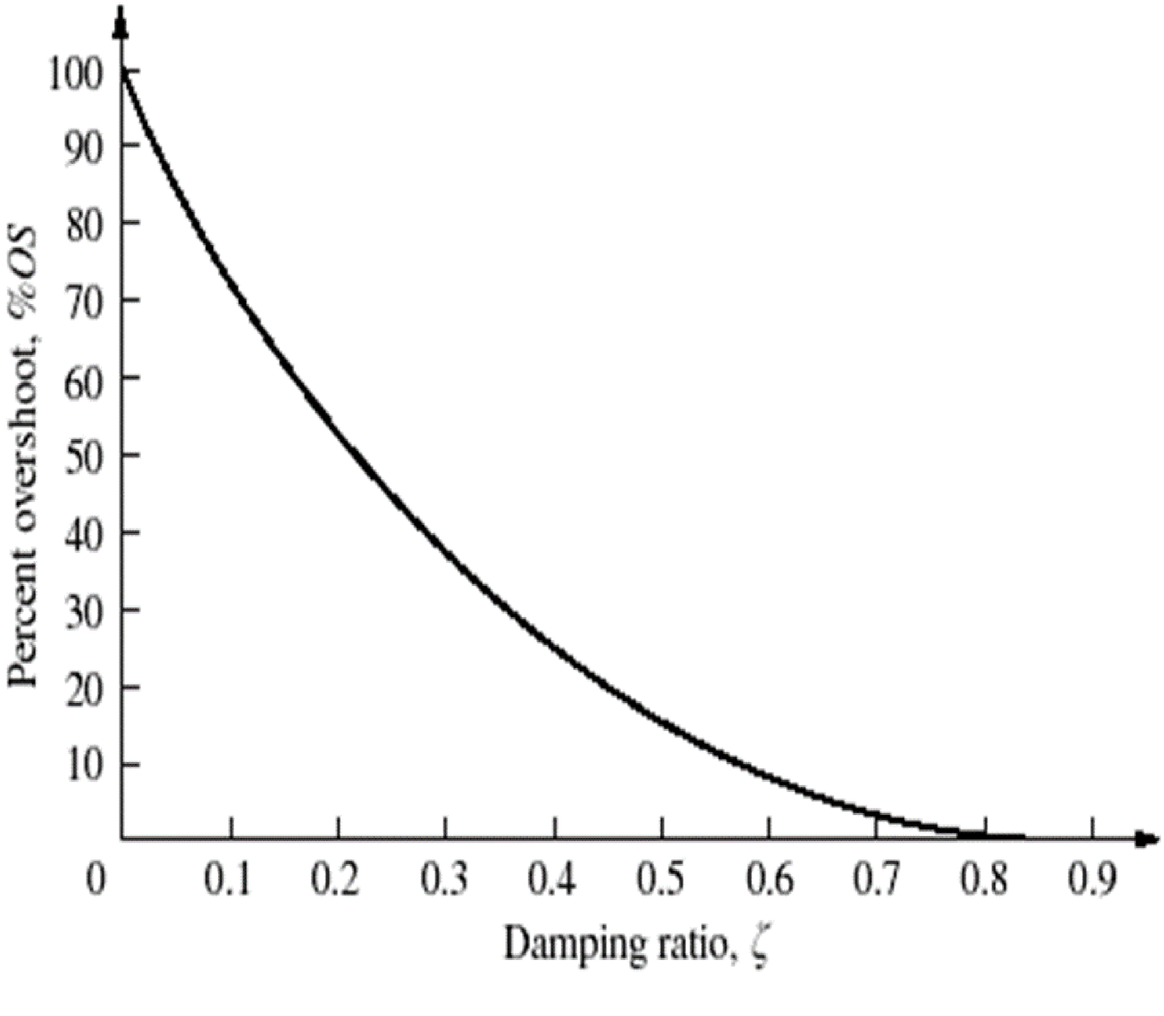

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Formula Sheet

$P = F/A$

$\rho = m/v$

$\dot{m} = \rho AV$

$P = P_g + P_{atm}$

$P = \rho gh$

$$\text{Bulk Modulus } \beta = -\frac{dP}{dv/v}$$

$$\tau = \mu \, du/dy$$

$$h = \frac{4\sigma}{\rho g s d}$$

$$Z_1 + \frac{P_1}{\rho g} + \frac{V_1^2}{2g} = Z_2 + \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$$

$$V_1 = \sqrt{\frac{2g\,h\left(\frac{\rho_L}{\rho} - 1\right)}{\left(\frac{a_1}{a_2}\right)^2 - 1}}$$

$Q - W = \Delta U + \Delta PE + \Delta KE$

$W = \int PdV$

$P\,V^n = C$

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$$W = \frac{P_1 V_1 - P_2 V_2}{n - 1}$$

$W = P\,(v_2 - v_1)$

$$W = PV \ln\left(\frac{V_2}{V_1}\right)$$

$Q = C_d\,A\,\sqrt{2gh}$

$$V_1 = C\sqrt{2g\,h_2\left(\frac{\rho g_m}{\rho g} - 1\right)}$$

$$\sum F = \frac{\Delta M}{\Delta t} = \Delta \dot{M}$$

$F = \rho\,QV$

$Re = V\,L\,\rho/\mu$

$dQ = du + dw$

$du = cu\,dT$

$dw = pdv$

$pv = mRT$

$h = h_f + xhf_g$

$s = s_f + xsf_g$

$v = x\ Vg$

$$\dot{Q} - \dot{w} = \sum \dot{m} h$$

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$$F = \frac{2\pi L\mu}{L_n\left(\frac{R_2}{R_3}\right)}$$

$$ds = \frac{dQ}{T}$$

$$S_2 - S_1 = C_{pL}\ \mathrm{L_n}\frac{T_2}{T_1}$$

$$S_g = C_{pL}\ \mathrm{L_n}\frac{T}{273} + \frac{h_{fg}}{T_f}$$

$$S = C_{pL}\ \mathrm{L_n}\frac{T_f}{273} + \frac{hf_g}{T_f} + C_{pu}\ \mathrm{L_n}\frac{T}{T_f}$$

$$\mathrm{S_2 - S_1 = MC_p\ L_n\frac{T_2}{T_1} - MRL_n\frac{P_2}{P_1}}$$

$$F_D = \frac{1}{2}CD\ \rho \mathrm{u}^2 s$$

$$F_L = \frac{1}{2}\mathrm{C_L}\rho u^2 s$$

$$S_p = \frac{d}{ds}(P + \rho g Z)$$

$$Q = \frac{\pi \mathrm{D}^4 \Delta p}{128\mu L}$$

$$h_f = \frac{64}{R}\left(\frac{L}{D}\right)\left(\frac{\mathrm{v}^2}{2g}\right)$$

$$\mathrm{h_f = \frac{4fLv^2}{d2g}}$$

$$\mathrm{f = \frac{16}{Re}}$$

$$h_m = \frac{Kv^2}{2g}$$

$$h_m = \frac{k(V_1 - V_2)^2}{2g}$$

$$\zeta = \left(1 - \frac{T_L}{T_H}\right)$$

$$S_{gen} = (S_2 - S_1)) + \frac{Q}{T}$$

$$W = (U_1 - U_2) - T_o(S_1 - S_2) - T_0 S_{gen}$$

$$W_u = W - P_o(V_2 - V_1)$$

$$W_{rev} = (U_1 - U_2) - T_0(S_1 - S_2) + P_0(V_1 - V_2)$$

$$\Phi = (U - U_0) - T(S - S_0) + Po(V - V_o)$$

$$I = ToS_{gen}$$

$$V = r\omega$$

$$\lambda = \mu \frac{V}{t}$$

$$F = \frac{2\pi L\mu u}{L_n\left(\frac{R_2}{R_1}\right)}$$

$$T = \frac{\pi^2 \mu N}{60t}\left(R_1^4 - R_2^4\right)$$

$$p = \frac{\rho g Q H}{1000}$$

END OF FORMULA SHEET

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