OCD31

UNIVERSITY OF BOLTON

WESTERN INTERNATIONAL COLLEGE FZE

BENG (HONS) MECHANICAL ENGINEERING

SEMESTER ONE EXAMINATION 2019/2020

ADVANCED THERMOFLUIDS & CONTROL SYSTEM

MODULE NO: AME 6015

Date: Thursday 16th January 2020 **Time: 1:00pm – 3:30pm**

INSTRUCTIONS TO CANDIDATES:

There are 6 questions.

Answer 4 questions.

All questions carry equal marks.
Attempt TWO questions from PART A and TWO questions from PART B

Marks for parts of questions are shown in brackets.

CANDIDATES REQUIRE:

Thermodynamic properties of fluids tables are provided

Take density of water = 1000 kg/m^3
Formula sheets provided

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PART A

Q1.

a) The velocity distribution through a circular pipe shown in Figure Q1a. for viscous flow at any radius r is given by

$$u = \frac{1}{4\mu}\left(-\frac{\partial p}{\partial x}\right)(R^2 - r^2)$$

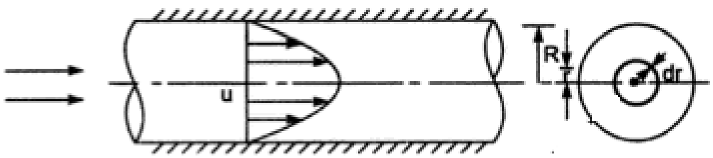

Figure Q1a. Circular pipe

i) Prove that the maximum velocity of flow is two times the average velocity of flow.

(10 marks)

ii) Compute an expression for Hagen Poiseuille's formula using the above parameters.

(8 marks)

b) A fluid of viscosity 0.9Ns/m^2 and specific gravity 1.2 is flowing through a circular pipe of diameter 130mm.The maximum shear stress at the pipe wall is given as 190.8N/m^2,evaluate the following

i) The pressure gradient

(3 marks)

ii) The average velocity

(2 marks)

iii) Reynolds number of the flow

(2 marks)

Total 25 marks

Please turn the page

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Q2.

a) Water at 30°C flows at a rate of 45 litres/s in a cast iron pipe of 30cm diameter and 20m length. The system includes a sudden entrance (k_e= 0.5), gate valve (k_g=0.15) , globe valve (k_{gv}=10) and a fully opened ball valve (k_{bv}=0.05)

Given the kinematic viscosity of water at 30°C = 1.008 x 10^{-6} m^2/s. The surface roughness value for cast iron = 0.26mm. Determine the following:

i. Define kinematic viscosity and its relationship with density of fluid

(2 marks)

Using the data given in the Q2a. Evaluate the following:

ii. Reynolds Number

(2 marks)

iii. Friction factor from Moody diagram

(3 marks)

iv. Major head loss

(4 marks)

v. Minor head loss

(4 marks)

vi. Total head loss

(3 marks)

b) Steam enters an engine at an absolute pressure of 8MPa and at a temperature of 450°C.It is exhausted at a pressure of 1.2 bar. The steam at exhaust is 0.9 dry. Using the data from the steam table determine the following:

i) Drop in enthalpy

(3 marks)

ii) Change in entropy

(2 marks)

iii) Sketch the process in T-S diagram

(2 marks)

Total 25 marks

Please turn the page

Q3.

a) A shaft having a diameter of 60mm rotates centrally in a journal bearing having a diameter of 60.25mm and length of 125mm.The angular space between the shaft and the bearing is filled with oil having viscosity of 0.9 poise. Determine the power absorbed in the bearing when the speed of rotation is 700 r.p.m.

(6 marks)

b) Air at 20^{0}C and 1.05 bar occupies 0.045m^3. The air is heated at constant volume until the pressure is 4bar.Then it is cooled at constant pressure back to original temperature. Determine the following:

i. Evaluate the work done for each process

(4 marks)

ii. Evaluate the heat transfer for each process

(4 marks)

iii. Evaluate the change in entropy for each process

(4 marks)

iv. Represent the cycle on T-S and p-v plot.

(4 marks)

v. Differentiate between isochoric, adiabatic and isothermal using p-v diagram

(3 marks)

Take Specific heat capacity at constant volume,C_v =0.718kJ/kgK and gas constant,R= 287 J/kgK

Total 25 marks

PART B

Q4.

a) The electric power industry is primarily interested in energy conversion, control, and distribution. It is critical that computer control be increasingly applied to the power industry in order to improve the efficient use of energy resources. The modern, large-capacity plants require automatic control systems that account for the interrelationship of the process variables and optimum power production. Draw the block diagram for the Turbine-Generator control.

(5 marks)

b) An industrial manufacturing system using a sampled data controller is shown in **Figure Q4.**

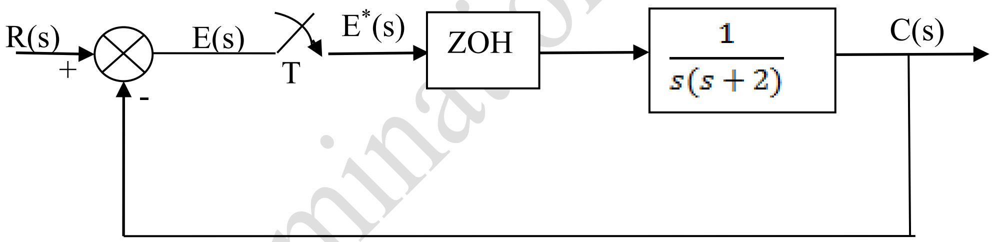


Figure Q4.

Analyse the stability of the given sampled control system shown for sampling time T=1 sec.

(20 marks)

Total 25 marks

Q5.

A closed-loop control system is shown in **Figure Q5.**

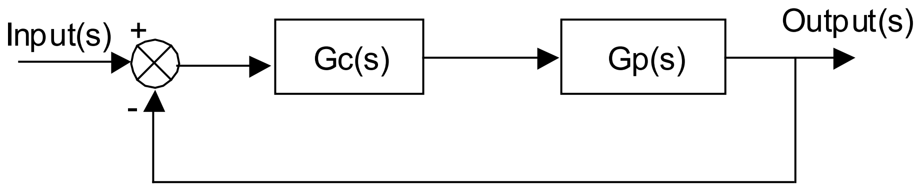


Figure Q5

Given $Gc(s) = 15 + 10\frac{Ki}{s} + 5sKd$ & $Gp(s) = \frac{2}{s^2 + 2s + 6}$

Where K_p is proportional gain, K_i is integral gain and K_d is derivative gain.

i) If K_i=0, Determine the value of K_d for critical damping.

(7 Marks)

ii) With K_d as determined in (a), determine the limiting value of K_i Such that stability is maintained.

(7 Marks)

iii) Find the K_i for a ramp input if $G_c(s)$ is a PI controller and the steady state error is less than 0.01.

(7 Marks)

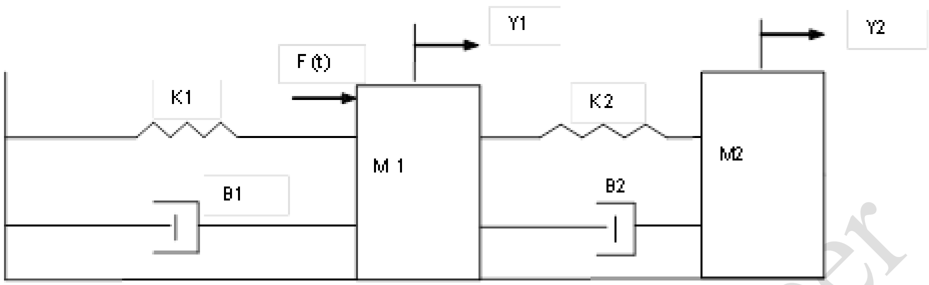
iv) Explain how does PID parameter affect the system dynamics.

(4 Marks)

Total 25 marks

Q6.

a) Develop the state space model of a simplified industrial robotic system shown in **FigureQ6a**



FigureQ6a

(15 marks)

b) The state equations of a mechanical system are given below. Analyse controllability and observability of the system.

$$\dot{x}_1 = x_2$$
$$\dot{x}_2 = -2x_1 - 3x_2 + u$$
$$y = x_1 + x_2$$

(10 marks)

Total 25 marks

END OF QUESTIONS

Please turn the page for the Formula Sheet

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FORMULA SHEET

Thermofluids

$P = F/A$

$\rho = m/v$

$\dot{m} = \rho A V$

$P = P_g + P_{atm}$

$P = \rho g h$

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

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

$W = \int P dV$

$P V^n = C$

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

$W = P (v_2 - v_1)$

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

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

Formula Sheet continued over the page

Formula Sheet continued

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

$$\sum F = \frac{\Delta M}{\Delta t} = \Delta M^{\cdot}$$

$$F = \rho\, QV$$

$$\tau = -(\partial p/\partial x)\, r/2$$

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

$$\Delta p = (32\mu VL)/D^2$$

$$U = 1/(4\mu)\; -(\partial p/\partial x)\,(R^2 - r^2)$$

$$dQ = du + dw$$

$$du = Cv\, dT$$

$$dw = pdv$$

$$pv = mRT$$

$$h = h_f + xhf_g$$

$$s = s_f + xsf_g$$

$$v = x\, Vg$$

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

Formula Sheet continued over the page

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Formula Sheet continued

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

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

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

$$S_2 - S_1 = mR\ \mathrm{L_n}\frac{P1}{P2}$$

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

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

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

Formula Sheet continued over the page

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Formula Sheet continued

Process	*Index* n	*Heat added*	$\int_1^2 p\,dv$	*p, v, T relations*	*Specific heat, c*
Constant pressure	$n = 0$	$c_p(T_2 - T_1)$	$p(v_2 - v_1)$	$\frac{T_2}{T_1} = \frac{v_2}{v_1}$	c_p
Constant volume	$n = \infty$	$c_v(T_2 - T_1)$	0	$\frac{T_1}{T_2} = \frac{p_1}{p_2}$	c_v
Constant temperature	$n = 1$	$p_1 v_1 \log_e \frac{v_2}{v_1}$	$p_1 v_1 \log_e \frac{v_2}{v_1}$	$p_1 v_1 = p_2 v_2$	∞
Reversible adiabatic	$n = \gamma$	0	$\frac{p_1 v_1 - p_2 v_2}{\gamma - 1}$	$p_1 v_1^{\gamma} = p_2 v_2^{\gamma}$ $\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma - 1}$ $= \left(\frac{p_2}{p_1}\right)^{\frac{\gamma - 1}{\gamma}}$	0
Polytropic	$n = n$	$c_n(T_2 - T_1)$ $= c_v\left(\frac{\gamma - n}{1 - n}\right) \times (T_2 - T_1)$ $= \frac{\gamma - n}{\gamma - 1} \times$ work done (non-flow)	$\frac{p_1 v_1 - p_2 v_2}{n - 1}$	$p_1 v_1^{n} = p_2 v_2^{n}$ $\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{n - 1}$ $= \left(\frac{p_2}{p_1}\right)^{\frac{n - 1}{n}}$	$c_n = c_v\left(\frac{\gamma - n}{1 - n}\right)$

S. No.	*Process*	*Change of entropy (per kg)*
1.	General case	(*i*) $c_v \log_e \frac{T_2}{T_1} + R \log_e \frac{v_2}{v_1}$ (in terms of T and v) (*ii*) $c_v \log_e \frac{p_2}{p_1} + c_p \log_e \frac{v_2}{v_1}$ (in terms of p and v) (*iii*) $c_p \log_e \frac{T_2}{T_1} - R \log_e \frac{p_2}{p_1}$ (in terms of T and p)
2.	Constant volume	$c_v \log_e \frac{T_2}{T_1}$
3.	Constant pressure	$c_p \log_e \frac{T_2}{T_1}$
4.	Isothermal	$R \log_e \frac{v_2}{v_1}$
5.	Adiabatic	Zero
6.	Polytropic	$c_v \left(\frac{n - \gamma}{n - 1}\right) \log_e \frac{T_2}{T_1}$

Formula Sheet continued over the page

Formula Sheet continued

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

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

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

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

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

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

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

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

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

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

$\eta = (h_1 - h_2)/(h_1 - h_{f2})$

Formula Sheet continued over the page

Formula Sheet continued

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

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

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

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

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

$$I = ToS_{gen}$$

F = τ πDL

$$V = r\omega$$

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

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

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

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

Control system

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)

Formula Sheet continued over the page

Formula Sheet continued

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)

Second order Transfer Function

$$\text{TF} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

	Laplace Transforms	Z Transforms
A unit step function	$\frac{1}{s}$	$\frac{z}{z-1}$
Exponential Function	$\frac{1}{s+a}$	$\frac{z}{z-e^{-aT}}$
A unit ramp function	$\frac{1}{s^2}$	$\frac{zT}{(z-1)^2}$
	$1 - e^{-st}$	$1 - z^{-1}$

Bilinear Transformation

$$z = \frac{(1+\omega)}{(1-\omega)}$$

Controllability test matrix

$Q_c = [B : AB]$

Observability test matrix

$Q_o = [C^T : A^T C^T]$

END OF PAPER