OCD001

UNIVERSITY OF BOLTON

OFF CAMPUS DIVISION

WESTERN INTERNATIONAL COLLEGE FZE

BENG(HONS) MECHANICAL ENGINEERING

TRIMESTER TWO EXAMINATION 2021/2022

THERMOFLUIDS & CONTROL SYSTEM

MODULE NO: AME5013

Date: Tuesday 26th April 2022 **Time: 2:00pm -4:00pm**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions.

Answer FOUR 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 :

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

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PART A

Q1. a) Derive from Bernoulli's theorem expressions for the theoretical velocity and discharge through venturi meter in a pipe of diameter 'd1' creating a vena contracta at a diameter d2 as shown in **Figure Q1a**. Assume a U-tube differential manometer is connected to measure the pressure head 'h' from the readings . Assume all parameter units in SI system.

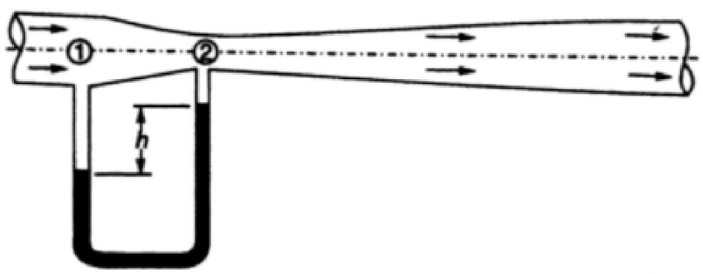

Figure Q1a. Venturi meter

(13 marks)

b) Explain the hydraulic co-efficients of velocity (C_v), contraction (C_c) and discharge (C_d) and hence prove that $C_d = C_c \times C_v$.

(7 marks)

c) An orifice meter with orifice diameter 150mm is inserted in a pipe of 300mm diameter. The pressure difference measured by a mercury oil differential manometer on the two sides of the orifice meter gives a reading of 500mm of mercury. Evaluate the rate of flow of oil of specific gravity 0.9, when the coefficient of discharge of the orifice meter is 0.64

(5 marks)

Total 25 marks
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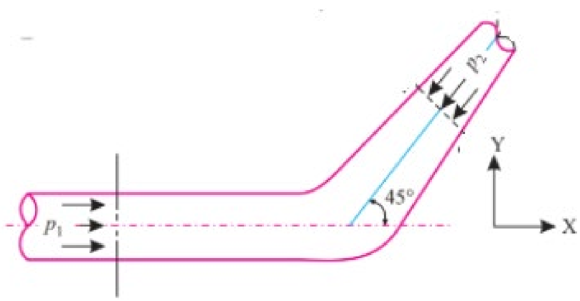
Q2. a) In a 45^0 bend a rectangular air duct of $1m^2$ cross sectional area is gradually reduced to $0.5m^2$ area as shown in FigureQ2a. The velocity of flow at the $1m^2$ section is 10m/s and the pressure is $2.9N/cm^2$. Take density of air as $1.16kg/m^3$ Determine the following:

i) Magnitude of the resultant force at the bend **(6 marks)**

ii) Direction of the resultant force at the bend. **(7 marks)**



FigureQ2a. Diagrammatic representation of 45° bends

b) A pipe 5 metre long is inclined at an angle of 15^0 with the horizontal. The smaller section of the pipe, which is at a lower level, is of 80mm diameter and the larger section of the pipe is of 240mm diameter as shown in **Figure Q2b.**

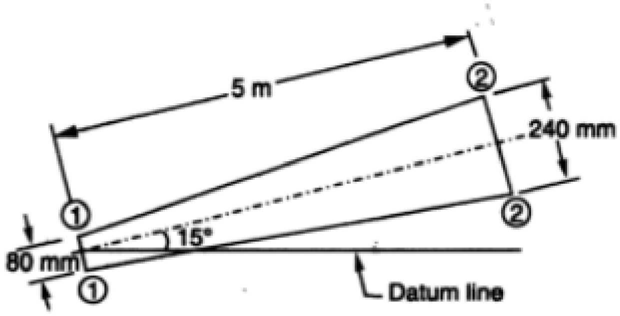


Figure Q2b.Inclined Pipe

Q 2b continued on next page…

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Q 2b continued….

Determine the following:

i. Difference of pressures between the two sections, if the pipe is uniformly tapering and the velocity of water at the smaller section is 1m/s. **(7 marks)**

ii. Differentiate between real and ideal flow **(2 marks)**

i. Express Bernoulli's Equation for ideal fluid and real fluid. **(3 marks)**

Total 25 marks

Q3 a) A fluid system contained in a piston and cylinder machine, passes through a complete cycle of four processes.Net heat transferred during a cycle is given as -170kJ.The system completes 100 cycles per min. Complete the following **Table Q3.a** showing the method for each item and compute the net rate of work output in kW. (15 marks)

Table Q3.a Heat, Work and internal energy transfer for a cycle

Process	Q (kJ/min)	W (kJ/min)	ΔE (kJ/min)
a–b	0	2,170	—
b–c	21,000	0	—
c–d	–2,100	—	–36,600
d–a	—	—	—

b) 8kg gas expands in a cylinder-piston device from 1000kPa,1 m^3 to 5kPa according to $PV^{1.2}$ =constant. If the specific internal energy of the gas decreases by 40kJ/kg, determine the

i. Work done in magnitude and direction **(3 marks)**

ii. heat transfer in magnitude and direction **(3 marks)**

iii. Differentiate between polytropic and adiabatic process **(4 marks)**

Total 25 marks

END OF PART A

PLEASE TURN THE PAGE FOR PART B…..

PART B

Q4 a) For the spring damper and mass system shown in **Figure Q4. (a)**, where

M1 = 2 Kg, K1 = 4 N/m, B1 = 5 Ns/m
M2 = 3 Kg, K2 = 1 N/m, B2 = 6 Ns/m
F(t) = force applied

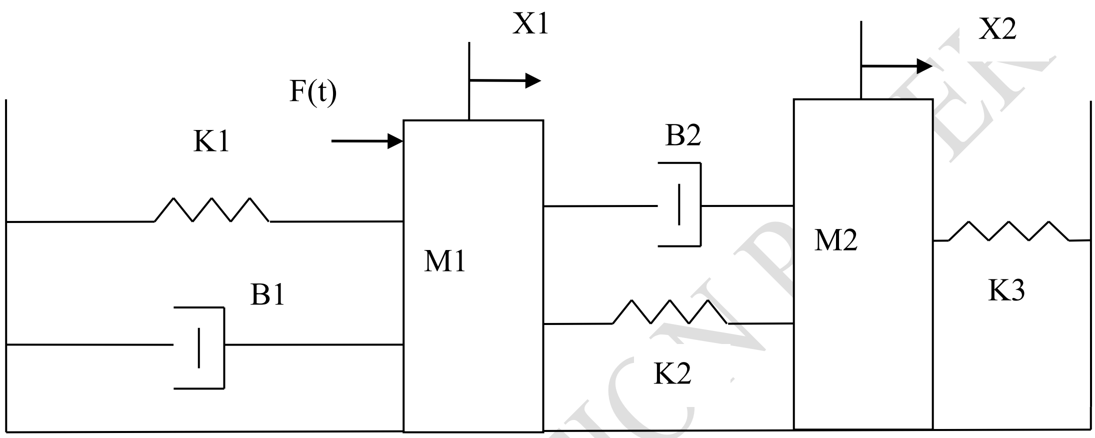

Figure Q4. (a) Spring damper mass system

(i) Develop differential equations for the system given in **Q4.(a)** **(3 marks)**

(ii) Determine the Laplace transforms of the differential equations obtained from **Q4(i)** above. **(3 marks)**

(iii) Determine the transfer function G(s) = $X_1(s)/F(s)$, 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). **(11 marks)**

Q4 continued over the page…

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Q4 continued…

b) Which of the following systems are stable, critically stable, and unstable?

i) pole -4; zero +1

ii) pole +1; no zero

iii) pole 0,-1,-2 ; zero -1

iv) Poles 1+2j,1-2j; zero -2

(8 marks)

Total 25 marks

Q5 a) The forward path transfer function of a unity feedback speed control system is given by

$$G(s) = \frac{2}{s(s+3)}$$

Derive an expression for unity step response of the system.

(10 marks)

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Q5 continued…

b) Block diagram for a closed loop control system for a thermostatically controlled air-conditioning system for an automobile is shown in **Figure Q5.(b).**

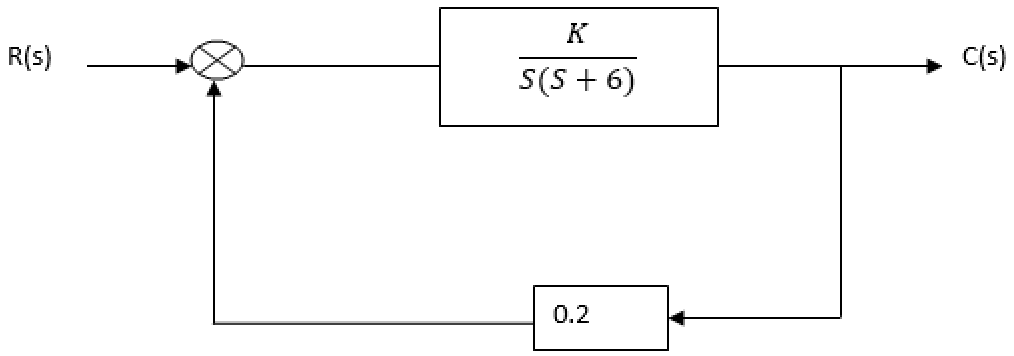

Figure Q5. (b) Thermostatically controlled air-conditioning system

The system is to have a damping ratio of 0.7. Determine the value of K to satisfy this condition and calculate the time domain specifications for the value of K determined.

(10 marks)

c) A robotic arm has an open loop transfer function for its angular position of

$$G(s) = \frac{10}{(s+1)(s+2)}$$

Evaluate the steady state error when a unit step input is applied to the systems.

(5 marks)

Total 25 marks

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Q6 a) Large welding robots are widely used in automobile assembly lines. The welding head is moved to different positions on the automobile bode, and rapid, accurate response is required. The characteristic equation for the welding system is

$$s^4 + 6s^3 + 11s^2 + 6s + 0.6K = 0$$

Using Routh-Hurwitz stability criterion to determine the range of values of K for the system which will result in stability.

(7 marks)

b) Reduce the following block diagram for an air traffic control systems shown in **Figure Q6. (b)** and determine the system transfer function.

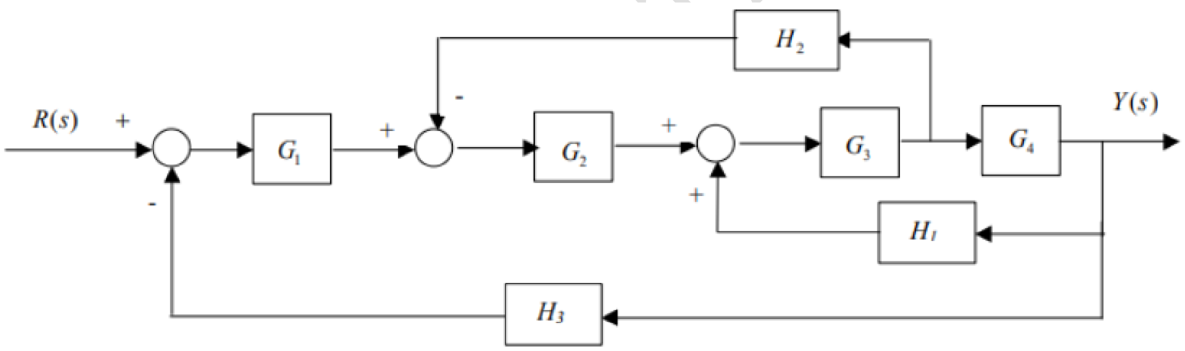

Figure Q6. (b) Block diagram for an air traffic control systems

(10 marks)

c) Evaluate and justify the selection of specific sensors and actuators that can be employed in boiler automation system for continuous monitoring of temperature, pressure and water level.

(8 marks)

Total 25 marks

END OF QUESTIONS

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FORMULA SHEET

R= 287 J/ Kg K

P = F/A

$\rho = m/V$
$\dot{m} = \rho AV$

$P = \rho gh$

Bernoulli's Equations

Q= A v

Q=V/t

$$h = x\left(\frac{sg}{so} - 1\right)$$

$$\frac{p}{\rho g} + \frac{v^2}{2g} + Z = constant$$

Flow meter Equation

$$Q = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$$

Fluid Force Calculation at the bend

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

$$F_x = \rho Q(v_{1x} - v_{2x}) + (p_1A_1)_x + (p_2A_2)_x$$

$$F_y = \rho Q(v_{1y} - v_{2y}) + (p_1A_1)_y + (p_2A_2)_y$$

$$F_R = \sqrt{Fx^2 + Fy^2}$$

Thermodynamics

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

$Q = mC\Delta T$
$PV = mRT$

$C_p - C_v = R$

$$Cp = \frac{\gamma R}{\gamma - 1}$$

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$$Cv = \frac{R}{\gamma - 1}$$

$$\frac{Cp}{Cv} = \gamma$$

Process	*Index* n	*Heat added*	$\int_1^2 pdv$	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)	$\frac{p_1 v_1 - p_2 v_2}{n - 1}$	$p_1 v_1^n = p_2 v_2^n$ $\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{n - 1}$ $= \left(\frac{p_2}{p_1}\right)^{\frac{n - 1}{n}}$	$c_n = c_v\left(\frac{\gamma - n}{1 - n}\right)$

Control Systems

Laplace Transforms

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

$$e^{-at} \longleftrightarrow \frac{1}{s+a}$$

$$\frac{d\,x(t)}{dt} \longleftrightarrow sX(s) - X(0)$$

$$\frac{d^2\,x(t)}{dt^2} \longleftrightarrow s^2X(s) - sX(0) - X'(0)$$

Block Diagram Reduction

Blocks with feedback loop

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

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

Blocks $G_1(S)$ & $G_2(s)$ in series $G(s) = G_1(S) * G_2(s)$

Blocks $G_1(S)$ & $G_2(s)$ in parallel $G(s) = G_1(S) + G_2(s)$

Steady-State Error

$$e_{ss} = \lim_{s\to 0}[s[1 - G_o(s)]\theta_i(s)] \quad \text{(For the open-loop system)}$$

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

Time Response for second-order systems

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

$$\phi = \tan^{-1}(\frac{\sqrt{(1-\zeta^2)}}{\zeta})$$

$$t_r = (\pi - \phi)/\omega_d$$

$$t_p = \pi/\omega_d$$

$$ts = \frac{4}{\zeta\omega_n}$$

$$Mp. = \exp(\frac{-\zeta\pi}{\sqrt{(1-\zeta^2)}}) \times 100\%$$

END OF FORMULA SHEET

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