OCD004

UNIVERSITY OF BOLTON

OFF CAMPUS DIVISION

WESTERN INTERNATIONAL COLLEGE

BENG (HONS) MECHANICAL ENGINEERING

SEMESTER TWO EXAMINATION 2023/24

THERMOFLUIDS & CONTROL SYSTEM

MODULE NO: AME5013

Date: 9th May 2024 **Time:** 10:00am-12:00

INSTRUCTIONS TO CANDIDATES:

There are SIX questions.

Answer any 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) The space between two square flat parallel plates is filled with oil. Each side of the plate is 720 mm. The thickness of the oil film is 15 mm. The upper plate, which moves at 3 m/s requires a force of 120 N to maintain the speed. Determine: (i) The dynamic viscosity of the oil; (ii) The kinematic viscosity of oil if the specific gravity of oil is 0.95.

(6 marks)

b) A vertical sharp-edged orifice 120 mm in diameter is discharging water at the rate of 98.2 litres/sec. under a constant head of 10 metres. A point on the jet, measured from the vena contracta of the jet has co-ordinates 4.5 metres horizontal and 0.54 metre vertical. Find the following for the orifice. (i) Co-efficient of velocity, (ii) Co-efficient of discharge, and (iii) Co-efficient of contraction.

(6 marks)

c) A horizontal venturimeter with inlet diameter 200 mm and throat diameter is employed to measure the flow of water. The reading of the differential manometer connected to the inlet is 180 mm of mercury. If the co-efficient of discharge is 0.98, determine the rate of flow.

(6 marks)

d) A rough plastic pipe 500 mm in diameter and 300 m in length carrying water with a velocity of 3 m/s, has an absolute roughness of 0·25 mm and a kinematic viscosity of 0·9 centistokes, (i) Is the flow turbulent or laminar? (ii) What are the head lost in friction?

For laminar flow, $f = 64/Re$

For turbulent flow, $f = 2log_{10}(R/k) + 1.74$

(7 marks)

Total 25 marks

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Q2. a) The water is flowing through a tapering pipe having diameters 300 mm and 150 mm at sections 1 and 2 respectively. The discharge through the pipe is 40 litres/sec. The section 1 is 10 m above datum and section 2 is 6 m above datum. Find the intensity of pressure at section 2 if that at section 1 is 400 kN/m^2.

(10 marks)

Also state Bernoulli's theorem.

(2 marks)

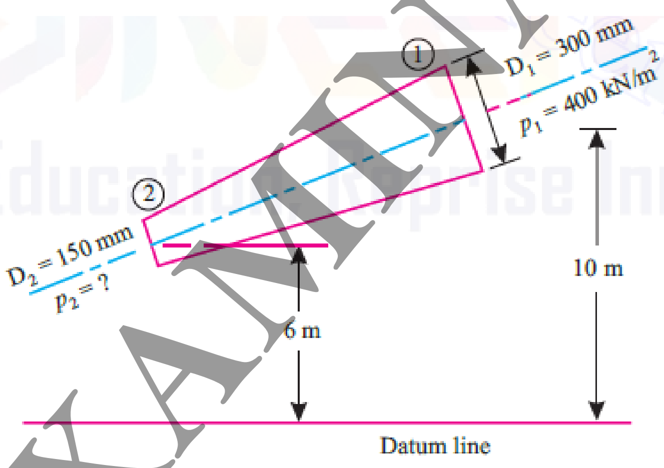

Figure Q2a. Line diagram of the flow system

b) Two pipes of diameters 400 mm and 200 mm are each 300 m long. When the pipes are connected in series the discharge through the pipeline is 0.10 m^3/s, find the loss of head incurred. What would be the loss of head in the system to pass the same total discharge when the pipes are connected in parallel? Take k = 0.33, friction factor = 0·0075 for each pipe.

(13 marks)

Total 25 marks

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Q3. 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 -340kJ.The system completes 200 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)

Process	Q (kJ/min)	W (kJ/min)	ΔE (kJ/min)
1—2	0	4340	—
2—3	42000	0	—
3—4	−4200	—	−73200
4—1	—	—	—

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

b) 10kg 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

(5marks)

ii. heat transfer in magnitude and direction

(5marks)

Total 25 marks

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PART B

Q4.

For the spring damper and mass system shown in figure Q4. (a), were

M1 = 2 Kg, K1 = 1 N/m, B1 = 3 Ns/m
M2 = 3 Kg, K2 = 1 N/m, B2 = 2 Ns/m

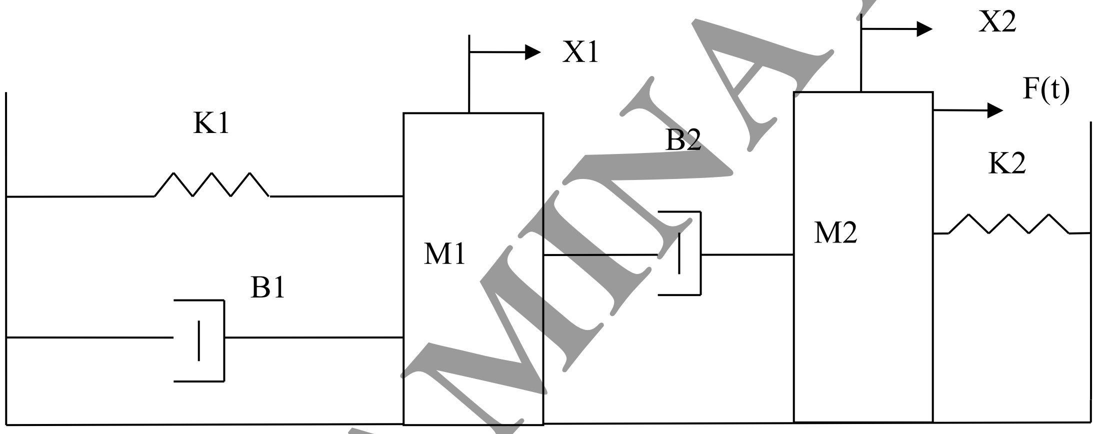

Figure Q4. (a) Spring damper mass system

(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) = X1(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).

(9 marks)

(iv) Compare the characteristics of open-loop and closed-loop control systems. Evaluate the differences in their operational principles, performance, and applicability within engineering systems.

(5 marks)

Q4 continues over next page…
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Q4 continued…

(v) Explain how pole placement in the S-plane influences the stability of a control system, considering its effect on system dynamics and overall performance. Discuss the implications of pole location on system stability and response characteristics. (5 marks)

Total 25 marks

Q5. a) Assess the time response properties of the closed loop control system depicted in Figure Q5.(a) for regulating the temperature in an automobile's air-conditioning system with step input.

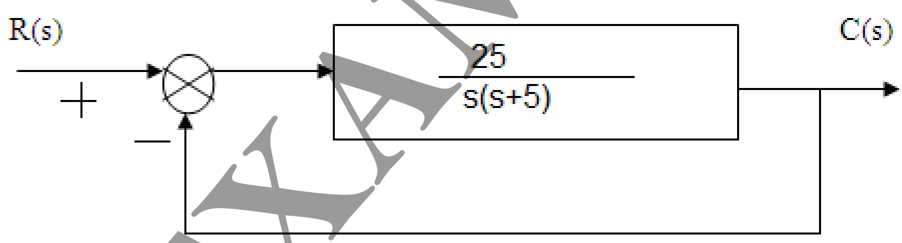

Figure Q5. (a) Thermostatically controlled air-conditioning system

(18 marks)

(b) The forward path function of a unity feedback control system is given by

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

Obtain the unit step response of the system.

(7 marks)

Total 25 marks

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Q6. (a) In automobile assembly lines, large welding robots are extensively employed, with the welding head being directed to various positions where responsive movement is imperative. The characteristic equation governing the welding system's dynamics is provided below. Using the Routh-Hurwitz stability criterion, evaluate the system stability.

$S^5 + 1.5s^4 + 2s^3 + 4s^2 + 5s + 10 = 0$ (13 marks)

(b) Reduce the following block diagram shown in **Figure Q6.b** to determine the system transfer function.

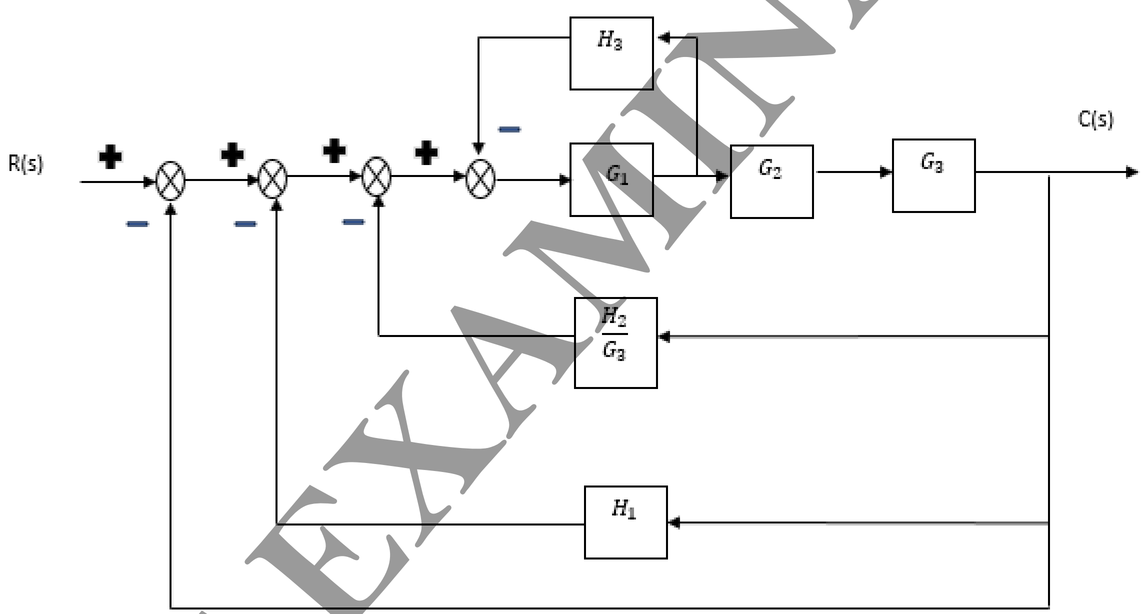

Figure Q6.b

(12 marks)

Total 25 marks

END OF QUESTIONS

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FORMULA SHEET

$R = 287$ J/ Kg K

$P = F/A$

$\rho = m/V$

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

$P = \rho g h$

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

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

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

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

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

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Thermodynamics

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

$Q = mC\,\Delta T$

$PV = mRT$

$C_p - C_v = R$

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

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

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

Control Systems

Laplace Transforms

A unit impulse function 1

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

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

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

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

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

Block Diagram Reduction

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)

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

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

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

Time Response for second-order systems

Standard second order Characteristic Equation = $s^2+2\zeta\omega_n+\omega_n^2$

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

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

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

$$t_p = \pi/\omega_d$$

$$ts = \frac{4}{\zeta\omega_n} \quad (2\%)$$

$$ts = \frac{3}{\zeta\omega_n} \quad (4\%)$$

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

END OF FORMULA SHEET