OCD010

UNIVERSITY OF BOLTON

OFF CAMPUS DIVISION

STUDY WORLD LANKA CAMPUS

BENG(HONS) MECHANICAL ENGINEERING

SEMESTER ONE EXAMINATION 2018/2019

ADVANCED THERMOFLUIDS & CONTROL SYSTEM

MODULE NO: AME6005

Date: 30TH September 2018 **Time: 09:00am – 11:00am**

INSTRUCTIONS TO CANDIDATES:

There are 6 questions.

Answer 4 questions.

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

Marks for parts of questions are shown in brackets.

CANDIDATES REQUIRE :

Thermodynamic properties of fluids tables are provided

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PART A

Q1. a) Water at 25°C flows steadily through the box shown in Figure Q1a, entering station-A at 2 m/s. Both entering and leaving stations are circular pipes with diameters 9cm and 4cm respectively. Calculate the horizontal and vertical forces required to hold the system against the momentum.

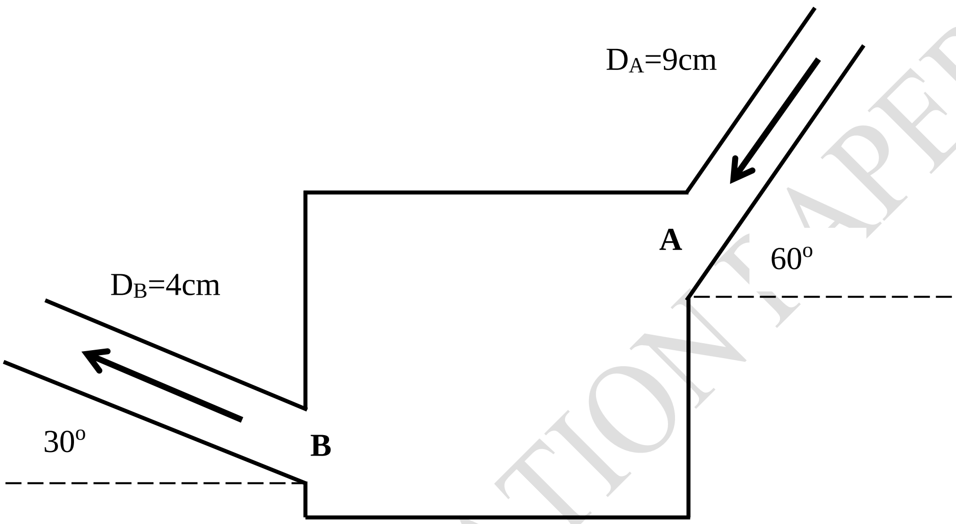

Figure Q1a.

(12 marks)

b) The pressure drop per unit length Δp/L in a porous, rotating duct depends upon average velocity U, density ρ, viscosity μ, duct height h, wall injection velocity U_i, and rotation rate ω. Considering ρ, U and h as repeating variables defines in Buckingham pi theorem, express this relationship in dimensionless form.

(13 marks)

Total 25 marks

Please turn the page

Q2. a) Briefly explain following terms related to internal duct (pipe) flow.

i. Laminar and Turbulent flow
ii. Velocity boundary layer
iii. Entrance region
iv. Fully developed flow

(8 marks)

b) The system in Figure Q2b consists of 800 m of 4 cm cast-iron pipe, two 45° and six 90° flanged long-radius elbows, one fully open flanged globe valve, one gate valve, one angle valve and a sharp exit into a reservoir. If the elevation at point A is 100 m, what gage pressure is required at point A to deliver 0.006 m^3/s of water at 25°C into the reservoir?

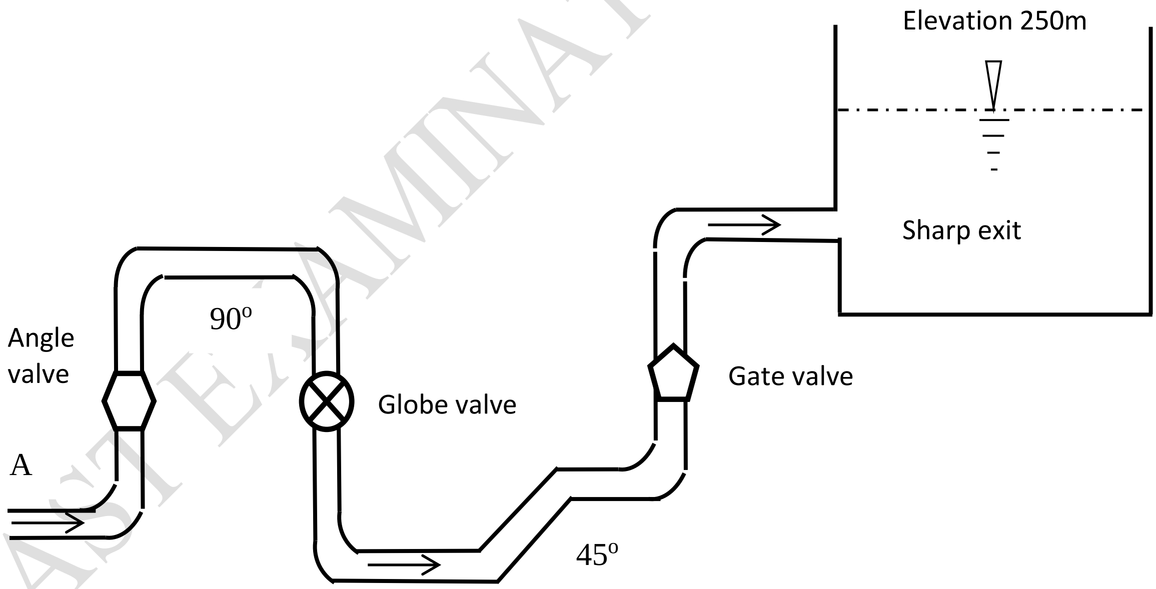

Figure Q2b

(17 marks)

Total 25 marks

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Q3. (a) A piston–cylinder device contains 0.8 kg of atmospheric air initially at 100 kPa and 27°C. The atmospheric air is now compressed slowly in a Polytropic manner process during which $PV^{1.3}$ = constant until the volume is reduced by one-third. Determine the work done and the heat transfer for this process.

(13 marks)

(b) Steam flows steadily through an adiabatic turbine. The inlet conditions of the steam are 10 MPa, 450°C, and 100 m/s, and the exit conditions are 10 kPa, 95 percent quality, and 30 m/s. The mass flow rate of the steam is 16 kg/s. Determine

i. The change in kinetic energy
ii. The power output
iii. The turbine inlet and outlet areas

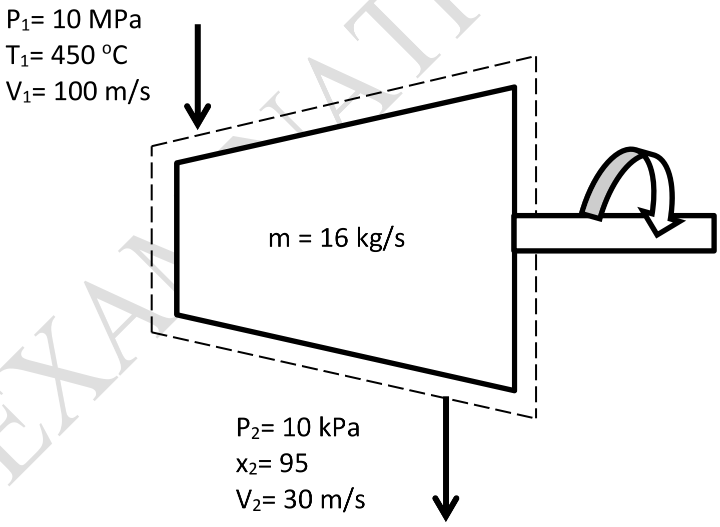

Figure Q3b

(12 marks)

Total 25 marks

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Q4. The gas-turbine portion of a combined gas–steam power plant has a pressure ratio of 15. Air enters the compressor at 300 K at a rate of 14 kg/s and is heated to 1500 K in the combustion chamber. The combustion gases leaving the gas turbine are used to heat the steam to 400°C at 10 Mpa in a heat exchanger. The combustion gases leave the heat exchanger at 420 K. The steam leaving the turbine is condensed at 15 kPa. Assuming all the compression and expansion processes to be isentropic, For air, assume constant specific heats at room temperature. Determine,

i. Air compressor and gas turbine outlet air temperatures
ii. Gas power cycle net power output
iii. The mass flow rate of the steam
iv. The net power output of steam power cycle
v. the thermal efficiency of the combined cycle.

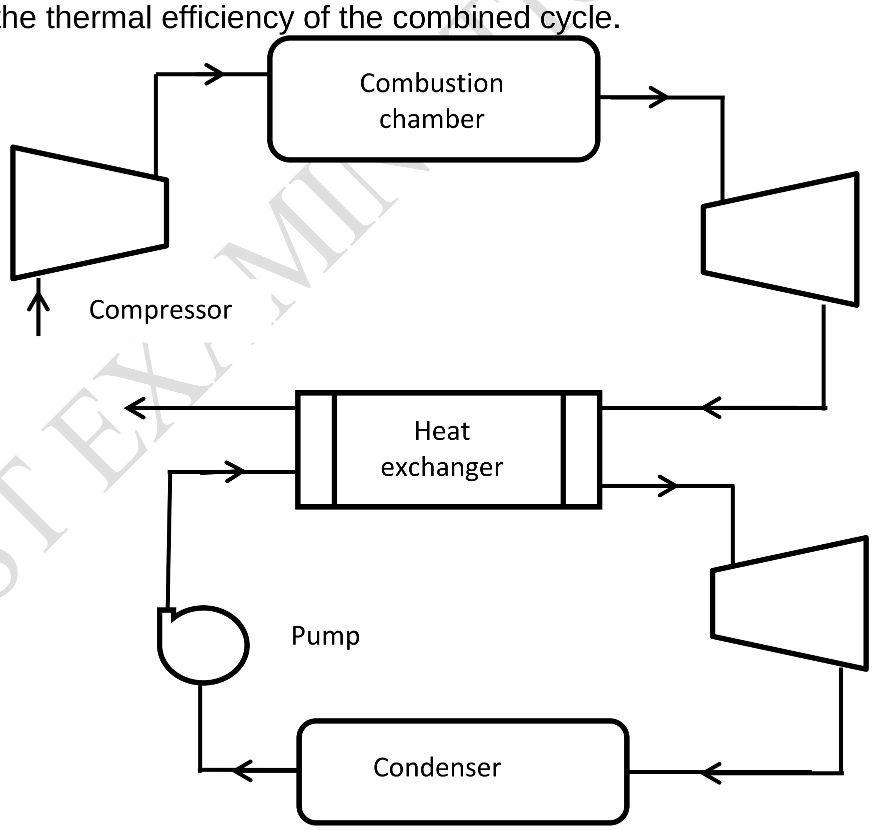

Figure Q4

Total 25 marks

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PART B

Q5. (a) Describe the importance of stability in control systems.

(4 marks)

(b) For an automated control system open loop transfer function is given as follows. Considering unity feedback control,

$$G(s) = \left(K_P + \frac{K_I}{s}\right)\frac{1}{s(s+2)}$$

i. Find the characteristic equation of the system

ii. Referring RH criteria find the condition of stability related to K_P and K_I.

(12 marks)

I Draw the bode plot for below transfer function

$$G(s)H(s) = \frac{14(s+9)^2}{(s+2)(s+5)(s+7)(s+13)}$$

(9 marks)

Total 25 marks

Q6. (a) Develop a state model for below transfer function following diagonal method used in state space analysis.

$$TF = \frac{1}{(s+2)(s+5)(s+7)(s+13)}$$

(15 marks)

(b) i. Explain the physical meaning of PID controller referring sketches graphs.

ii. Write down three advantages of PID controller

(10 marks)

Total 25 marks

END OF QUESTIONS

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FORMULA SHEET

$P = F/A$, $\rho = m/v$, $\dot{m} = \rho AV$, $P = P_g + P_{atm}$, $P = \rho gh$

$Q - W = \Delta U + \Delta PE + \Delta KE$, $W = \int PdV$, $PV^n = C$

$$W = \frac{P_1 V_1 - P_2 V_2}{n - 1} \qquad W = P(v_2 - v_1)$$

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

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

$$V_1 = C\sqrt{2g\, h_2 \left(\frac{\rho g_m}{\rho g} - 1\right)}, \quad \sum F = \frac{\Delta M}{\Delta t} = \Delta \dot{M}, \quad F = \rho QV, \quad \tau = -(\partial p/\partial x)\, r/2$$

$Re = VD\rho/\mu$, $\Delta p = (32\mu VL)/D^2$, $Q = du + dw$, $du = Cv\, dT$, $dw = pdv$

$$pv = mRT, \quad h = h_f + xh_{fg}, \quad s = s_f + xs_{fg}, \quad v = x V_g, \quad \dot{Q} - \dot{w} = \sum \dot{m} h, \quad F = \frac{2\pi L\mu}{L_n\left(\frac{R_2}{R_3}\right)}$$

$$F_D = \frac{1}{2} CD\, \rho u^2 s, \quad F_L = \frac{1}{2} C_L \rho u^2 s, \quad S_p = \frac{d}{ds}(P + \rho gZ), \quad Q = \frac{\pi D^4 \Delta p}{128\mu L}$$

$$h_f = \frac{64}{R}\left(\frac{L}{D}\right)\left(\frac{v^2}{2g}\right), \quad h_f = \frac{4fLv^2}{d2g}, \quad f = \frac{16}{Re}, \quad h_m = \frac{Kv^2}{2g}, \quad h_m = \frac{k(V_1 - V_2)^2}{2g}$$

$$\eta = \left(1 - \frac{T_L}{T_H}\right), \quad \eta = (h_1 - h_2)/(h_1 - h_{f2}), \quad S_{gen} = (S_2 - S_1) + \frac{Q}{T}$$

$F = \tau \pi DL$

Blocks with feedback loop

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

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G(s) = $\dfrac{Go(s)}{1 - Go(s)H(s)}$ (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)

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

	Laplace Transforms	**Z Transforms**
A unit impulse function	1	
A unit step function	$\dfrac{1}{s}$	$\dfrac{z}{z-1}$
Exponential Function	$\dfrac{1}{s+a}$	$\dfrac{z}{z-e^{aT}}$
A unit ramp function	$\dfrac{1}{s^2}$	
	$1 - e^{-st}$	$1 - z^{-1}$

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Recommended Roughness Values for Commercial Ducts

		ϵ		
Material	**Condition**	**ft**	**mm**	**Uncertainty, %**
Steel	Sheet metal, new	0.00016	0.05	±60
	Stainless, new	0.000007	0.002	±50
	Commercial, new	0.00015	0.046	±30
	Riveted	0.01	3.0	±70
	Rusted	0.007	2.0	±50
Iron	Cast, new	0.00085	0.26	±50
	Wrought, new	0.00015	0.046	±20
	Galvanized, new	0.0005	0.15	±40
	Asphalted cast	0.0004	0.12	±50
Brass	Drawn, new	0.000007	0.002	±50
Plastic	Drawn tubing	0.000005	0.0015	±60
Glass	—	Smooth	Smooth	
Concrete	Smoothed	0.00013	0.04	±60
	Rough	0.007	2.0	±50
Rubber	Smoothed	0.000033	0.01	±60
Wood	Stave	0.0016	0.5	±40

Resistance Coefficients $K = h_m/[V^2/(2g)]$ for Open Valves, Elbows, and Tees

	Nominal diameter, in								
	Screwed				Flanged				
	$\frac{1}{2}$	1	2	4	1	2	4	8	20
Valves (fully open):									
Globe	14	8.2	6.9	5.7	13	8.5	6.0	5.8	5.5
Gate	0.30	0.24	0.16	0.11	0.80	0.35	0.16	0.07	0.03
Swing check	5.1	2.9	2.1	2.0	2.0	2.0	2.0	2.0	2.0
Angle	9.0	4.7	2.0	1.0	4.5	2.4	2.0	2.0	2.0
Elbows:									
45° regular	0.39	0.32	0.30	0.29					
45° long radius					0.21	0.20	0.19	0.16	0.14
90° regular	2.0	1.5	0.95	0.64	0.50	0.39	0.30	0.26	0.21
90° long radius	1.0	0.72	0.41	0.23	0.40	0.30	0.19	0.15	0.10
180° regular	2.0	1.5	0.95	0.64	0.41	0.35	0.30	0.25	0.20
180° long radius					0.40	0.30	0.21	0.15	0.10
Tees:									
Line flow	0.90	0.90	0.90	0.90	0.24	0.19	0.14	0.10	0.07
Branch flow	2.4	1.8	1.4	1.1	1.0	0.80	0.64	0.58	0.41

END OF PAPER