



INTERNAL ASSESSMENT APPROVAL FORM (INCLUDING COLLABORATIVE PROVISION)

This form is used to ensure that assessment specifications have been through an internal review process prior to external examination/approval and release to students. It should be completed for each assessment for a particular module. The assessment tasks, criteria and marking scheme should accompany this form.

PARTNER (and taught location if relevant):	Coleg Sirgar				
EXTERNAL EXAMINER NAME:	TO BE ADVISED				
ASSESSMENT AUTHOR:	CHRIS DAVIES				
MODULE TITLE:	THERMOFLUIDS AND MECHANICS				
MODULE CODE:	SEDM6022		MODULE LEVEL:	6	
COMPONENT NO. (e.g. 1 of 2):	1 (THERMOFLUIDS COMPONENT)		COMPONENT WEIGHTING (e.g. 50% of the module):	50%	
ASSESSMENT PERIOD	☐ Semester 1	☐ Semester 1 Re-sit	☒ Semester 2	☐ Semester 2 Re-sit	Other, please state
TYPE OF ASSESSMENT:	☐ Coursework		☒ Examination MAINT TEST PAPER		☐ Practical
LANGUAGE OF ASSESSMENT:	ENGLISH		TRANSLATION REQUIRED (Y/N):	N	
FOR EXAMINATIONS ONLY. SPECIFY BELOW ANY ADDITIONAL MATERIAL(S) TO BE USED IN THE EXAMINATION					
This box will expand as you type					

INTERNAL MODERATOR PLEASE TICK TO INDICATE THAT THE ASSESSMENT INCLUDES:		Please ✓		Comments
		YES	NO	
1	Tasks that are specified clearly, accurately and comprehensibly, with appropriate use of language and neat presentation	✓		
2	Tasks which enable the module learning outcomes to be demonstrated (as per the module syllabus)	✓		
3	Tasks which conform to the assessment described in the module syllabus	✓		
4	Tasks which are written at the appropriate level of the Framework for Higher Education Qualifications (see http://www.qaa.ac.uk/docs/qaa/quality-code/qualifications-frameworks.pdf?sfvrsn=170af781_14).	✓		
5	Clear criteria for assessment and guidance about how marking/grading will be applied	✓		
6	Guidance about expected evidence for submission, e.g. essay or report, word count, bibliography and references	n/a		Formal Examinations
7	Reference to good academic conduct, for example referencing, plagiarism and Turnitin	n/a		
8	Actions to complete n/a This box will expand as you type			
SIGNATURE OF APPROVAL:		SIGNATURE		DATE
INTERNAL MODERATOR: I confirm that this version of the assessment specification is ready		Adam Twell		07/10/19

to be sent to the Partnership Team Leader		
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ONLY TO BE COMPLETED IF THE ASSESSMENT IS LINKED TO A COLLABORATIVE PARTNER

PARTNERSHIP TEAM LEADER PLEASE TICK TO INDICATE THAT THE ASSESSMENT INCLUDES:		Please ✓		Comments
		YES	NO	
1	Tasks that are specified clearly, accurately and comprehensibly, with appropriate use of language and neat presentation			
2	Tasks which enable the module learning outcomes to be demonstrated (as per the module syllabus)			
3	Tasks which conform to the assessment described in the module syllabus			
4	Tasks which are written at the appropriate level of the Framework for Higher Education Qualifications (see http://www.qaa.ac.uk/docs/qaa/quality-code/qualifications-frameworks.pdf?sfvrsn=170af781_14).			
5	Clear criteria for assessment and guidance about how marking/grading will be applied			
6	Guidance about expected evidence for submission, e.g. essay or report, word count, bibliography and references			
7	Reference to good academic conduct, for example referencing, plagiarism and Turnitin			
8	Actions to complete <i>This box will expand as you type</i>			
SIGNATURE OF APPROVAL:		SIGNATURE		DATE
PTL: I confirm that this version of the assessment specification is ready to be sent to the External Examiner				

UWTSD PROVISION: please submit the completed document to the appropriate Programme Director.

COLLABORATIVE PROVISION: please submit the completed document (or make available electronically) to the Partnership Team Leader. This must be in accord with specific arrangements for sharing electronic documents (e.g. via SharePoint or similar).

The assessment tasks, criteria and marking scheme should accompany this form

THIS DOCUMENT IS ALSO AVAILABLE IN WELSH

**UNIVERSITY OF WALES:
TRINITY SAINT DAVID**



**PRIFYSGOL CYMRU:
Y DRINDOD DEWI SANT**

LOCATION: COLEG SIR GAR (GRAIG)

LLEOLIAD: COLEG SIR GAR (GRAIG)

LEVEL 6

LEFEL 6

**EXAMINATION PERIOD
MAY 2020**

**CYFNOD ARHOLIADAU
MAI 2020**

**MODULE CODE: SGDM6022
THERMOFLUIDS AND APPLIED MECHANICS
THERMOFLUIDS PAPER**

TIME: 2 HOURS

ANSWER THREE QUESTIONS OUT OF FIVE

Equipment or materials required

Calculators are permitted

Steam and refrigeration tables will be provided.

Adnoddau neu ddefnyddiau sydd eu hangen

Caniateir cyfrifiemellau

Bydd tablau Stêm a Rheweiddiad yn cael eu darparu

QUESTION 1

Hot combustion gases at 1500 K flow with 44 m/s across steel pipes to boil water inside the pipes at 225°C. The pipes have a diameter $D = 10\text{cm}$ and a surface temperature of 227°C.

Find the rate of heat transfer per metre pipe length.

Hint use the empirical formula

$$\text{Nu} = 0.26 \text{Re}^{0.5} \text{Pr}^{1/3}$$

For the calculation of the Nusselt number.

[25 marks]

Total marks for Question 1 = 25 Marks

QUESTION 2

a) In a gas turbine cycle, what is the main purpose for using a heat exchanger?

[7 Marks]

b) A gas turbine takes in air at 20 °C and operates with the following conditions:

Mass flow rate of 20 kg/s, Pressure ratio of 12, maximum temperature of 1000 °C, compressor isentropic efficiency of 82% and turbine isentropic efficiency of 90%.

Calculate:

i) The power output.

[13 Marks]

ii) The thermal efficiency of the engine.

[5 Marks]

Total marks for Question 2 = 25 Marks

QUESTION 3

a) Explain, with the aid of sketches, the difference between vapour-compression and vapour-absorption refrigeration cycles.

[6 Marks]

b) Refrigerant 134a is the working fluid in an ideal vapour-compression refrigeration cycle, shown in Figure Q3, which communicates thermally with a cold region at 0°C and a warm region at 26°C . Saturated vapour enters the compressor at 0°C and saturated liquid leaves the condenser at 26°C . The mass flow rate of the refrigerant is 0.08 kg/s . Determine

i) The compressor power, in kW

[5 Marks]

ii) The refrigeration capacity

[6 Marks]

iii) The coefficient of performance

[4 Marks]

iv) The coefficient of performance of a Carnot refrigeration cycle operating between warm and cold regions at 26 and 0°C , respectively.

[4 Marks]

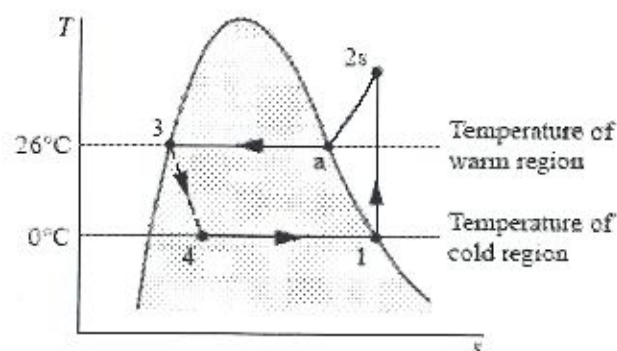


Figure Q3

Total marks for Question 3 = 25 Marks

QUESTION 4

a) In a steam turbine cycle, what is the main purpose for using reheat?

[7 marks]

b) A combined heat and power scheme uses an open cycle gas turbine for power generation with the exhaust gas energy used to raise steam for process heating. The gas turbine has a single stage compressor and a single stage turbine.

Air enters the compressor from atmosphere at a pressure of 1 bar and a temperature of 20°C . The overall pressure ratio of the plant is 8/1, the maximum cycle temperature is 850°C and the net power output is 15MW. The isentropic efficiency of the compressor stage and of the turbine is 0.85 and the fuel has a calorific value of 42 MJ/kg. The specific heat of air and combustion gas may be assumed constant at 1.005 kJ/kgK.

The gases leaving the turbine pass through a steam generator heat exchanger to generate the process steam before exhausting to atmosphere at 200°C . The process steam generated is at a pressure of 20 bar and a temperature of 300°C . Condensate is then returned to the process heat exchanger for reheating, as a saturated liquid at 20 bar.

Taking isentropic index γ for air as 1.4 throughout, calculate:

i) The mass flow rates of fuel, air and steam

[13 marks]

ii) The heat available for process heating

[5 marks]

Total marks for Question 4 = 25 Marks

QUESTION 5

(a) Exhaust gases flowing through a tubular heat exchanger at the rate of 0.35 kg/s are cooled from 400 °C to 110 °C by water initially at 10 °C. The specific heat capacities of exhaust gases and water are taken as 1.13 and 4.19 kJ/ kg K respectively, and the overall heat transfer coefficient from gases and water is 145 W/m² K. Calculate the surface area required when cooling water flow is 0.35kg/s, (a) for parallel flow and (b) for counter flow. Comment on the results.

[15 marks]

(b) Discuss the effect of fouling in a heat exchanger and highlight how this can be allowed for in design calculations.

[10 marks]

Total marks for Question 5 = 25 Marks



EXAMINATION SOLUTIONS

(to accompany the examination paper sent to the external examiner
but NOT to be seen by students)

X THERMOFLUIDS MAIN PAPER X

Programme:	BSC HONS MECHANICAL ENGINEERING	Level:	6
Module:	SGDM6022 THERMOFLUIDS AND APPLIED MECHANICS		
Author:	CHRIS DAVIES	Page:	11

Q1	Question	Marks
	THE FILM TEMPERATURE IS $T_f = \frac{1}{2} (T_s + T_{\infty}) = \frac{1}{2} (227 + 273 + 1500) = 1000K$ AT THIS TEMPERATURE PROPERTIES OF AIR IN HANDBOOK ARE $\mu = 42 \times 10^{-6} \text{ kg/sm} \quad k = 0.074 \text{ W/mK} \quad Pr = 0.73$ FROM IDEAL GAS LAW $p = \frac{P}{RT} = \frac{101.3}{(0.287 \times 1000)} = 0.353 \text{ kg/m}^3$ $\therefore Re = \frac{\rho V D}{\mu} = \frac{0.353 \times 44 \times 0.1}{42 \times 10^{-6}} = 36981$ $Nu = 0.26 (36981)^{0.8} \times (0.73)^{1/4} \quad Nu = 128.8$ $h = \frac{Nu}{KD} = \frac{128.8}{0.074 \times 0.1} = 95.3 \text{ W/m}^2K.$ $\therefore Q = h \pi D \Delta T$ $Q = 95.3 \times \pi \times 0.1 (1500 - 500)$ $Q = 29.9 \text{ kW/m}$	(3) (3) (5) (3) (3) (3) (5)



Q2	Question	Marks
a)	DESCRIBE POSITION OF HEAT EXCHANGER TO PREVENT AIR BUREAU COMBUSTION CHAMBER. INCLUDE SIMPLE DIAGRAM TO ILLUSTRATE. COMMENT ON REDUCED HEAT NEEDED AND THEREFORE IMPROVED CYCLE EFFICIENCY	(7)
b)	$T_1 = 293 \text{ K}$ $T_3 = 1273 \text{ K}$ $\frac{W_{12}}{m} = T_2 = T_1 \left(\frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} = 293 (12)^{\frac{0.4}{1.4}} = 595.9 \text{ K} \quad (2)$ $\frac{Q_c}{m} = \frac{T_2 - T_1}{T_2' - T_1} = 0.82 = \frac{595.9 - 293}{T_2' - 293} \quad T_2' = 662.4 \text{ K} \quad (2)$ $\frac{W_{34}}{m} = T_4 = 1273 \left(\frac{1}{12} \right)^{\frac{0.4}{1.4}} = 625.9 \text{ K} \quad (2)$ $\frac{Q_r}{m} = \frac{T_3 - T_4'}{T_3 - T_4} = 0.9 = \frac{1273 - T_4'}{1273 - 625.9} \quad \therefore T_4' = 690.6 \text{ K} \quad (2)$ $W_{\text{NET}} = m c_p (T_3 - T_4' - T_2' - T_1)$ $\therefore W_{\text{NET}} = 20 \times 1.005 [(1273 - 690.6) - (662.4 - 293)]$ $W_{\text{NET}} = 4.28 \text{ MW} \quad \text{OUTPUT POWER} \quad (5)$ $\eta_c = \frac{1273 - 690.6 - 662.4 - 293}{1273 - 662.4}$ $\eta_c = \underline{\underline{34.9\%}} \quad (5)$	
		25

Q3	Question	Marks
b(i)	Compressor power = $0.08 (264.7 - 247.23)$ $= \underline{\underline{1.4 \text{ kW}}}$	(3)
b(ii)	The refrigeration capacity is the heat transfer rate to the refrigerant passing through the evaporator $Q = \dot{m} (h_1 - h_4)$ $= 0.08 (247.23 - 85.75)$ $= \underline{\underline{12.99 \text{ kW}}}$	(6)
b(iii)	C.O.P. = $\frac{Q_{4-1}}{W_{12}} = \frac{247.23 - 85.75}{264.7 - 247.23} = \underline{\underline{9.24}}$	(4)
b(iv)	For a Carnot vapour refrigeration cycle operating at 299 K and 273 K. C.O.P. = $\frac{299}{299 - 273} = \underline{\underline{10.5}}$	(4)
c)	Vapour-compression cycles utilise a liquefiable vapour as the refrigerant. A throttling valve is normally used for the expansion and a compressor for the compression of the vapour. Vapour-absorption systems operate with a condenser ~~throttle valve~~ and an evaporator in the same way as a vapour-compression system but the compressor is replaced by an absorber and generator. Heat is supplied in the generator and can come from a range of sources. Sketch diagrams provided.	~~7/6~~ (6) <u>25</u>

Q4	Question	Marks
(b)		(1)
(a)	$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = 8^{0.286} \therefore T_2 = 293 \times 1.813 \quad T_2 = 531 \text{ K} \quad (2)$	(2)
	$T_c = \frac{T_2 - T_1}{T_2' - T_1} = \frac{531 - 293}{T_2' - 293} = \frac{238}{T_2 - 286} \quad T_2' = 573 \text{ K} \quad (2)$	(2)
	$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} = 1.813 \therefore T_4 = 619 \text{ K} \quad (2)$	(2)
	$T_c = \frac{T_3 - T_4}{T_3 - T_4'} = \frac{1123 - T_4'}{1123 - 619} \therefore T_4' = 694.6 \text{ K} \quad (2)$	(2)
	$\therefore 15 \times 10^6 = \dot{m} \times 1.005 [(1123 - 694.6) - (573 - 293)]$ $\dot{m}_a = 100.6 \text{ kg/s} \quad (2)$	(2)
(ii)	$\dot{m}_s \times 42000 = 100.6 \times 1.005 \times (1122 - 573)$ $\therefore \dot{m}_s = 1.324 \text{ kg/s} \quad (2)$	(2)
(ii)	Heat transfer in steam condenser $= 100.6 \times 1.005 \times (694.6 - 473)$ $= 22404 \text{ kW}$	
	From steam tables $h_b = 3025 \text{ kJ/kg}$ $h_a = 909 \text{ kJ/kg}$ (at 20 bar) $\therefore 22404 = \dot{m}_s (3025 - 909)$ $\dot{m}_s = 10.59 \text{ kg/s}$	
	Water to the process = $10.59 \times 2116 = 22404 \text{ kg/s}$ (6)	(6)
(a)	Comments on increasing dryness fraction and limiting corrosion (damage within the turbine). Greater W.D. through turbine but increase heat input needed (3)	(3)

Q6	Q5	Question	Marks
		$400^{\circ}\text{C} \rightarrow 110^{\circ}\text{C}$ $\dot{m} = 0.35 \text{ kg/s}$ $C_{pG} = 1.13 \text{ kJ/kgK}$ $10^{\circ}\text{C} \rightarrow T_2$ $\dot{m} = 0.35 \text{ kg/s}$ $C_{pW} = 4.19 \text{ kJ/kgK}$ $400^{\circ}\text{C} \rightarrow 110^{\circ}\text{C}$ (a) Parallel flow $Q = \frac{M C_p \Delta T}{G \& G} = \frac{M C_p \Delta T}{W W W}$ $Q = 0.35 \times 1.13 \times (400 - 110) = 0.35 \times 4.19 (T_2 - 10)$ $T_{W2} = \frac{114.6}{0.35 \times 4.19} = T_{W2} - 10$ $T_{W2} = 88.2^{\circ}\text{C}$ (3) $Q = 0.35 \times 1.13 \times (400 - 110) = 114.6 \text{ kW}$ (3) $Q = U A \Delta \bar{T}_{in}$ $114.6 = 145 \times A \times \Delta \bar{T}_{in}$ $\Delta \bar{T}_{in} = \frac{\theta_1 - \theta_2}{\ln \theta_1 / \theta_2} = \frac{390 - 21.8}{\ln (390 / 21.8)} = \frac{368.2}{2.88}$ $= 127.8 \text{ K}$ (3) $A = \frac{114.6 \times 10^3}{145 \times 127.8} = 6.18 \text{ m}^2$ (3) (b) Counterflow $400^{\circ}\text{C} \rightarrow 120^{\circ}\text{C}$ $88.2^{\circ}\text{C} \leftarrow 10^{\circ}\text{C}$ $400^{\circ}\text{C} \rightarrow 120^{\circ}\text{C}$ $\Delta \bar{T}_{in} = \frac{\theta_1 - \theta_2}{\ln \theta_1 / \theta_2} = \frac{110 - 31.8}{\ln (110 / 31.8)}$ $\Delta \bar{T}_{in} = \frac{-201.8}{-1.04} = 193.6 \text{ K}$ $A = \frac{114.6 \times 10^3}{145 \times 193.6} = 4.08 \text{ m}^2$ (3) (c) Comments on why Fouling occurs and type of Fouling typically encountered. Comments on Fouling factor and units and how it can be included within design calculations (10)	

**UNIVERSITY OF WALES:
TRINITY SAINT DAVID**



**PRIFYSGOL CYMRU:
Y DRINDOD DEWI SANT**

LOCATION: COLEG SIR GAR (GRAIG)

LLEOLIAD: COLEG SIR GAR (GRAIG) A

LEVEL 6

LEFEL 6

**EXAMINATION PERIOD
AUGUST 2020**

**CYFNOD ARHOLIADAU
AWST 2020**

**MODULE CODE: SGDM6022
THERMOFLUIDS AND APPLIED MECHANICS
THERMOFLUIDS PAPER**

TIME: 2 HOURS

ANSWER THREE QUESTIONS OUT OF FIVE

Equipment or materials required

Calculators are permitted

Steam and refrigeration tables will be provided.

Adnoddau neu ddefnyddiau sydd eu hangen

Caniateir cyfrifiannellau

Bydd tablau Stêm a Rheweidddiad yn cael eu darparu

QUESTION 1

- a. What are the advantages of using reheat in some Rankine cycles?

[5 Marks]

- b. Consider a regenerative cycle using steam as the working fluid shown in Figure Q1. Steam leaves the boiler and enters the turbine at 4 MPa, 400 °C. After expansion to 400 kPa, some of the steam is extracted from the turbine for the purpose of heating the feed-water in an open feed-water heater. The pressure in the feed-water heater is 400 kPa, and the water leaving it is saturated liquid at 400 kPa. The steam not extracted expands to 10 kPa.

- (i) Determine the cycle efficiency.

[20 Marks]

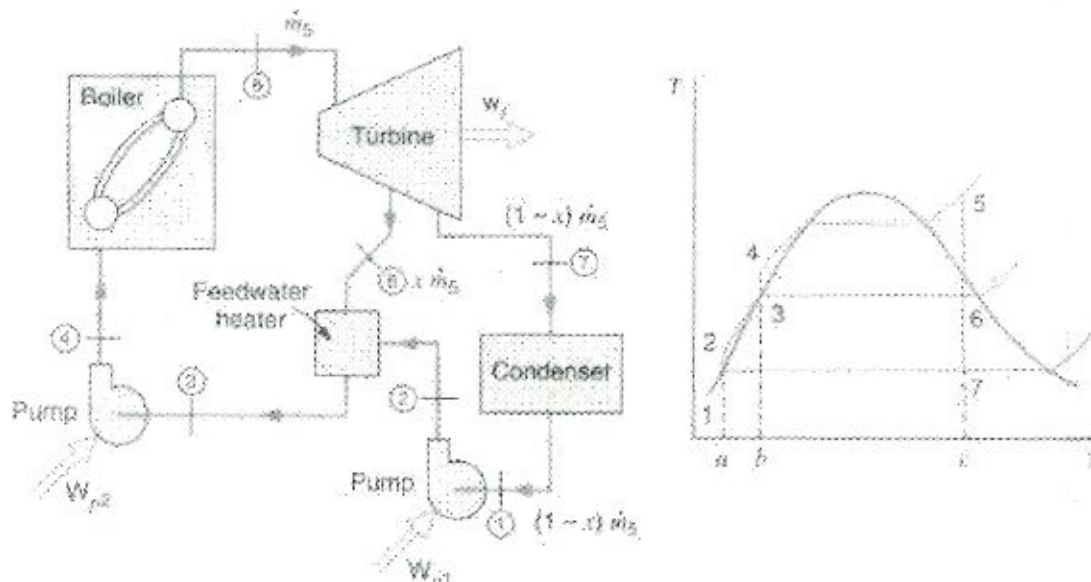


Figure Q1

Total marks for Question 1 = 25 Marks

QUESTION 2

A 5000 kW gas turbine generating set operates with two compressor stages with intercooling between stages; the overall pressure ratio is 9/1. A HP turbine is used to drive the compressors, and a LP turbine drives the generator. The temperature of the gases at entry to the HP turbine is 650° C and the gases leaving the LP turbine are reheated to 650°C after expansion through the first turbine. The exhaust gases leaving the LP turbine are passed through a heat exchanger to heat the air leaving the HP compressor. The compressors have equal pressure ratios and intercooling is complete between stages. The air inlet temperature to the unit is 15°C. The isentropic efficiency of each compressor stage is 0.8 and the isentropic efficiency of both turbines is 0.85; the heat exchanger thermal ratio is 0.75. A mechanical efficiency of 98% can be assumed for both the power shaft and the compressor turbine shaft. Neglecting all pressure losses and changes in Kinetic energy, Calculate:

- | | | |
|-------|----------------------|-------------------|
| (i) | the cycle efficiency | [15 marks] |
| (ii) | the work ratio | [5 marks] |
| (iii) | the mass flow rate | [5 marks] |

For air take $C_p = 1.005 \text{ KJ/kg K}$ and $\gamma = 1.4$, and for the gases in the combustion chamber and in the turbines and heat exchanger take $C_p = 1.15 \text{ KJ/kg K}$ and $\gamma = 1.333$. Neglect the mass of fuel.

Total marks for Question 2 = 25 Marks

QUESTION 3

A steam plant working on the Rankine cycle supplies steam to a turbine at a pressure of 50 bar and a temperature of 400°C . The steam expands in the turbine in two stages. Steam enters the high pressure stage and leaves dry saturated at a pressure of 2 bar. The steam is then reheated back to 250°C , at this pressure, before entry to the low pressure stage and expanded to a condenser pressure of 0.05 bar. The total power output of the two turbines is 15 MW.

Allowing for the feed pump work in your calculations, calculate:

- i) the mass flow rate of steam

[12 marks]

- ii) the heat rejected in the condenser

[5 marks]

- iii) the cycle efficiency.

[8 marks]

Take the expansion in the low pressure turbine to have an isentropic efficiency of 0.9, and assume the condensate is returned to the feed pump as a saturated liquid at a pressure of 0.05 bar.

Total marks for Question 3 = 25 Marks

QUESTION 4

A small scale Combined Heat and Power (CHP) system incorporates a small gas turbine with the exhaust gases from the turbine being used in a heat exchanger to produce hot water for a process.

The gas turbine operates with a pressure ratio of 4/1 with air entering the compressor at 15°C. The maximum cycle temperature for the gas turbine is 700 °C. The gas turbine is designed for a net power output of 2 MW, with single stage isentropic compression and expansion. The exhaust gases flow through the heat exchanger and exit to atmosphere at 200 °C. Water enters the heat exchanger at 30 °C at a flowrate of 10 kg/s. If the heat exchanger has an efficiency of 70% calculate:

i) the mass flow of turbine exhaust gases

[15 marks]

ii) the temperature of the water supplied to the process

[5 marks]

iii) the quantity of heat supplied to the process

[5 marks]

The following information should be used:-

- the turbine compression and expansion should be considered isentropic
- isentropic index $\gamma_{\text{air}} = 1.4$ throughout
- specific heat at constant pressure $c_p = 1.005 \text{ kJ/kgK}$ for air and combustion gas
- specific heat at constant pressure $c_p = 4.18 \text{ kJ/kgK}$ for water

Total marks for Question 4 = 25 Marks

QUESTION 5

- a) Explain what is meant by an 'electrical analogy' in heat transfer, and how this simplifies heat transfer calculations.

[10 marks]

- a) A spherical pressure vessel in a process plant contains a gas at 500 °C. The vessel is constructed from mild steel of 1 m diameter of wall thickness 20 mm.

It is lagged with 25mm of insulation and an outer cladding of fibreglass 10mm thick. The thermal conductivities of mild steel, insulation and fibreglass are 48, .05, and .04 W/mK respectively, and the outer surface heat transfer coefficient is 25 W/m²K.

If the inside surface temperature of the vessel is 500 °C, calculate:

- i) The rate of heat loss from the vessel if the outside air temperature is 20°C.

[8 marks]

- ii) The temperature of the outside surface of the cladding under these conditions.

[7 marks]

The mean radius of the wall of a sphere of inside and outside radii r_i and r_o respectively, can be taken as $r_m = \sqrt{r_i r_o}$

Total marks for Question 5 = 25 Marks

EXAMINATION SOLUTIONS

(to accompany the examination paper sent to the external examiner
but NOT to be seen by students)

Programme:	BSC MECHANICAL ENGINEERING	Level:	6
Module:	PSDM6015 THERMOFLUIDS 3 (BEST)		
Author:	CHRIS JAVIES	Page:	1/8

Q.1.	Question	Marks
(a)	COMMENTS ON REHEAT IN TERMS OF IMPROVING DRYNESS FRACTION THROUGH THE TURBINE. RELATES TO T-S DIAGRAM	(5)
(b)	$Z = \frac{W}{Q} = \frac{1(h_5 - h_6) + (1-y)(h_6 - h_7)}{(h_5 - h_1)}$ $t_6 = \frac{t_5 + t_7}{2} = \frac{500 + 45.8}{2} = 273^\circ\text{C}$ $t_7 = t_5 @ 0.1 \text{ bar} = 45.8^\circ$ $h_5 = h \text{ at } 4 \text{ bar, } 500^\circ\text{C} = 3445 \text{ kJ/kg}$ $h_3 = h_g \text{ at } 4 \text{ bar} = 605^\circ \text{ kJ/kg}$ $\text{Now } S_5 = S_6 = S_g \text{ at } 4 \text{ bar, } 500^\circ = 7.089 \text{ kJ/kgK}$ $\therefore \text{ At } 4 \text{ bar } \frac{7.089 - 1.766}{5.121} = x \quad x = 1$ $h_6 = h_g \text{ at } 4 \text{ bar} = 2739 \text{ kJ/kg}$ $\text{Also } S_5 = S_7 \quad \therefore 7.089 = 0.106 + x(8.868)$ $x = 0.787$ $h_7 = h_f + 0.787 h_{fg}$ $h_7 = 29 + 0.787(2501) \quad h_7 = 1997 \text{ kJ/kg}$ $\text{Also } y h_6 + (1-y) h_2 = h_3$ $h_2 = h_g \text{ at } 0.1 \text{ bar} = 24 \text{ kJ/kg}$	(5)



Q2	Question	Marks
	Q1 CONTINUED $y h_6 + h_2 - y h_2 = h_3$ $y h_6 - y h_2 = h_3 - h_2$ $y = \frac{h_3 - h_2}{h_6 - h_2}$ $y = \frac{605 - 25}{2739 - 25} = \underline{\underline{0.2145}}$ $\therefore Z_c = \frac{(3445 - 2739) + 0.21(2739 - 1997)}{3445 - 605}$ $Z_c = \frac{706 + 155.8}{2840}$ $Z_c = 30.3\%$	(5) (5) <u>25</u>



Q 2	Question	Marks
	$Z_c = \frac{\text{NET WORK OUTPUT}}{\text{HEAT SUPPLIED}}$ CONSIDER STAGE 1-2 $\frac{T_2'}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$ where $\frac{P_2}{P_1} = \sqrt{9}$ $\therefore T_2' = (3)^{0.4/1.4} \times 288 = 394 \text{ K}$ $Z_{LPC} = 0.8 = \frac{T_2' - T_1}{T_2 - T_1} \Rightarrow T_2 - T_1 = \frac{394 - 288}{0.8} = 132.5$ $\therefore T_2 = 132.5 + 288 = 420.5 \text{ K}$ $W \cdot D_{1-2} = C_p (T_2 - T_1) = 1.005 (420.5 - 288)$ $W \cdot D_{1-2} = 133.1 \text{ KJ/Kg}$ SINCE UNDERCODING IS COMPLETE WORK ON H.P.C. 3-4 WILL ALSO BE 133.1 KJ/Kg $\therefore W \cdot D_{HPT} = 2 \times 133.1 = 272 \text{ KJ/Kg}$ $W \cdot D_{6-7} = 272 = C_p (T_6 - T_7)$ $272 = 1.15 (923 - T_7) \therefore T_7 = 686.5 \text{ K}$ ALSO $Z_{HPT} = 0.85 = \frac{T_6 - T_7}{T_6 - T_7'} \Rightarrow 0.85 = \frac{923 - 686.5}{923 - T_7'}$ $\therefore T_7' = 645 \text{ K}$ Now $\frac{T_6}{T_7'} = \left(\frac{P_6}{P_7}\right)^{\frac{\gamma-1}{\gamma}} \Rightarrow \left(\frac{T_6}{T_7'}\right)^{\frac{\gamma}{\gamma-1}} = \frac{P_6}{P_7}$ $\frac{P_6}{P_7} = \left(\frac{923}{645}\right)^{1.333/0.333} = 4.19 \quad \frac{P_6}{P_7} = 4.19$ Now $\frac{T_8}{T_9'} = \left(\frac{P_8}{P_9}\right)^{\frac{\gamma-1}{\gamma}} \Rightarrow \frac{T_8}{T_9'} = (2.147)^{0.333/1.333}$ $T_8/T_9' = 1.211 \therefore T_9' = \frac{923}{1.211} = 762.6 \text{ K}$	(3) (3)

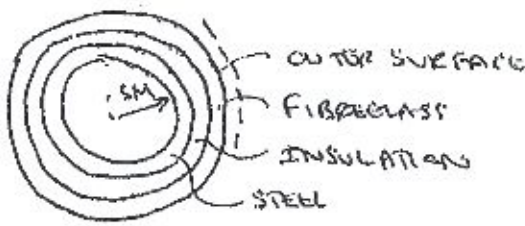
Q#	Question	Marks
	Q2 CONT $Z_{LPT} = 0.85 = \frac{T_8 - T_9}{T_8 - T_9}$ $0.85 (923 - 762.6) = 923 - T_9$ $T_9 = 786.7 K$ W.D = $C_p (T_8 - T_9)$ $= 1.15 (923 - 786.7) \times 0.98$ W.D = 153.7 kJ/kg ① Now needs to be considered Thermal Ratio of heat exchanger = $\frac{T_5 - T_4}{T_9 - T_4}$ $\therefore 0.75 = \frac{T_5 - 420.5}{786.7 - 420.5} \quad \therefore T_5 = 695.2 K$ $\therefore$ Heat supplied = $C_p (T_6 - T_5) + C_p (T_8 - T_9)$ $= 1.15 (923 - 695.2) + 1.15 (923 - 786.7)$ $= 534 \text{ kJ/kg}$ $Z_c = \frac{153.7}{534} = \frac{28.8\%}{\text{work}}$ Gross = $\frac{153.7}{0.98} = 429 \text{ kJ/kg}$ Work Ratio = $\frac{153.7}{429} = 0.358$ $P = \dot{M} W \quad \therefore 5000 = \dot{M} \times 153.7$ $\dot{M} = 32.6 \text{ kg/s}$	(3) (3) (3) (5) (5) 25



Q3	Question	Marks
	From tables $h_1 = 3196 \text{ kJ/kg}$ $h_2 = 2707 \text{ kJ/kg}$ $h_3 = 2971 \text{ kJ/kg}$ $h_4 = 2350 \text{ kJ/kg}$ $h_5 = 138 \text{ kJ/kg}$ $Z = \frac{h_3 - h_4'}{h_3 - h_4} = \frac{2971 - h_4'}{621}$ $h_4' = 2971 - (0.9 \times 621) = 2971 - 558.9$ $h_4' = 2412.1 \text{ kJ/kg}$ $h_6 - h_5 = \dot{m} (P_6 - P_5)$ $h_6 - h_5 = 0.001 (50 - 0.05) \times 10^5$ $h_6 - h_5 = 5.02 \text{ kJ/kg}$ <u>Turbine output</u> $= (h_1 - h_2) + (h_3 - h_4')$ $= (3196 - 2707) + (2971 - 2412.1)$ $= 489 + 558.9$ $= \underline{\underline{1047.9 \text{ kJ/kg}}}$ <u>Power output</u> $= \dot{m} \Delta h$ $15000 = \dot{m} \times 1047.9$ $\boxed{\dot{m} = 14.31 \text{ kg/s}}$	(12)

Q4	Question	Marks
(i)	Q3 CONTINUED HEAT REJECTED IN CONDENSER = $h_4' - h_5$ $= 2412.1 - 138$ $= 2274.1 \text{ kJ/kg}$ TOTAL HEAT REJECTED = 14.31×2274.1 $= \underline{\underline{32.5 \text{ MW}}}$	(5)
(iii)	$\eta_c = \frac{\text{WORK OUT}}{\text{HEAT IN}}$ $h_6 = h_5 + 5.02$ $h_6 = 138 + 5.02$ $h_6 = 143.02 \text{ kJ/kg}$ $= \frac{1047.9 - 5.02}{(h_1 - h_6) + (h_3 - h_2)}$ $= \frac{1047.9 - 5.02}{(3196 - 143.02) + (2971 - 2707)}$ $= \frac{1042.88}{3052.98 + 264}$ $\eta_c = 0.314$ <u>$\eta_c = 31.4\%$</u>	(8)
		<u>25</u>

Q 4	Question	Marks
	$T_2 = T_1 \left(\frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}}$ $T_2 = 288 (4)^{0.2857}$ $T_2 = 427.96 \text{ K}$ $\frac{T_3}{T_4} = 4^{0.2857}$ $T_4 = \frac{973}{1.486} = 654.8 \text{ K}$ $\text{NET WORK OUT} = C_p [(T_3 - T_4) - (T_2 - T_1)]$ $= 1.005 [(973 - 654.8) - (427.96 - 288)]$ $= 1.005 (318.2 - 139.96)$ $= 179.13 \text{ KJ/Kg}$ $\text{Power out} = \dot{m} W = 2000$ $\dot{m} = 2000 / 179.13 = 11.165 \text{ Kg/s} \quad (15)$ $\text{Heat ex} \quad \dot{m}_w C_{pw} (T_7 - T_6) = \dot{m}_s C_{ps} (T_4 - T_3)$ $10 \times 4.18 (T_7 - 303) = 11.165 \times 1.005 (654.8 - 473) \quad (5)$ $T_7 = 351.8 \text{ K}$ $\text{Heat to process} = 41.8 (351.8 - 303)$ $= 2.04 \text{ MW} \times 0.7 = 1.43 \text{ MW} \quad (5)$ ~~Overall efficiency~~	25

Q 6	Question	Marks
	USING ELECTRICAL ANALOGY $I = \frac{V}{R} \Rightarrow Q = \frac{(T_1 - T_2)}{R_T}$ $\therefore R_T = \text{THERMAL RESISTANCE}$ E.G RESISTANCES IN SERIES $R_T = R_i + R_{LU} + R_c$ $= \frac{1}{h_i A_i} + \sum \frac{x_c}{k A_m} + \frac{1}{h_o A_o}$ EXTRA RESISTANCES CAN BE ADDED AS REQ'D.  RESISTANCES OF VESSEL $\frac{x_c}{k A_m} = \frac{0.2}{48 \times 4\pi \times 0.5 \times 0.52}$ $= 0.0001275 \text{ K/W}$ INSULATION $\frac{x_c}{k A_m} = \frac{0.025}{0.05 \times 4\pi \times 0.52 \times 0.545}$ $= 0.14 \text{ K/W}$ FIBREGLASS $= \frac{x_c}{k A_m} = \frac{0.1}{0.04 \times 4\pi \times 0.545 \times 0.555}$ $= 0.0658 \text{ K/W}$ OUTSIDE SURFACE $= \frac{1}{h_o A_o} = \frac{1}{25 \times 4\pi \times 0.555^2}$ $= 0.01 \text{ K/W}$ TOTAL RESISTANCE $= 0.2159 \text{ K/W}$ $\therefore Q = (500 - 20) / 0.2159 = 2223.25 \text{ W}$	(10)

RESISTANCE UP TO OUTER SURFACE $= 0.2059 \text{ K/W}$

$$Q = \frac{500 - t_s}{0.2059} \quad \therefore t_s = 500 - (0.2059 \times 2223.25)$$

$$t_s = 42.23^\circ \text{C}$$

(8)

(7) 25 8