INTERNATIONAL MARITIME COLLEGE OMAN كلية عُمان البحرية الدولية

ACADEMIC YEAR 2021 –2022

Program	Year	Semester	Paper
PE	2	2	MAIN

MODULE NAME:	CHEMICAL ENGINEERING THERMODYNAMICS		
MODULE CODE:	TCET	EXAM DATE:	22/06/2022
TEACHER'S NAME:	Dr Luqman	DURATION:	120 Mins

Questions to be answered on:	Allowed requirements	Number of pages
Space provided on the question paper	Pen, Pencil & Calculator	(Incl. Cover Page): 15

Points of Attention:

- For each question, the maximum earned points are mentioned between brackets at the end of each question.
- Write very clearly! Answers that are not readable are not marked and don't get points!
- Make sure your answers are written to the point.
- All answers should be written **in English**.
- Write all the answers **in blue or black pen only (No pencil)**.
- Answer written in **Pencil** will not be marked.
- Use the **pencil** only for **diagrams & graphs & drawing**.
- Show all the calculation steps in the given space.
- When finished submit the question paper, together with the answer scripts and the signed cover page to the invigilator.
- Any cheating/copying may result in an instant failing of the examination.

FINAL MARKS

	40
	10

STUDENT NAME:	
STUDENT ID:	

Number of answer scripts: ……………………… **Invigilator:** ………….……..........

Student's signature: ……………………………… **Time of receipt:** …………….......

SECTION A

(10 marks)

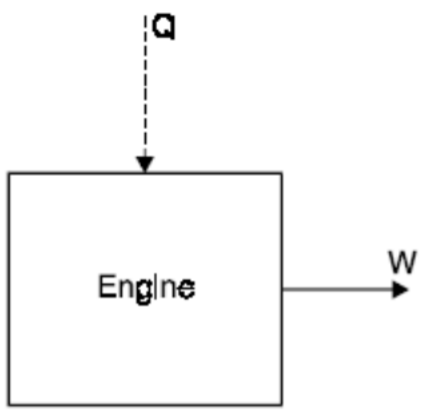
1. State and write mathematical expression for the First Law of Thermodynamics for a closed system.

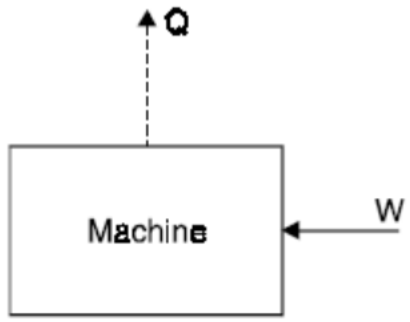
[2]

2. State one similarity and one difference between Isothermal system and Adiabatic System

[2]

3. Using our convention, state whether Q and W are positive (+) or negative (-). Write '+' or '-' beside the 'Q' and 'W' in the following diagrams [2]





4. Derive the relationship: $C_p = C_v + R$ for a perfect gas. [4]

SECTION B

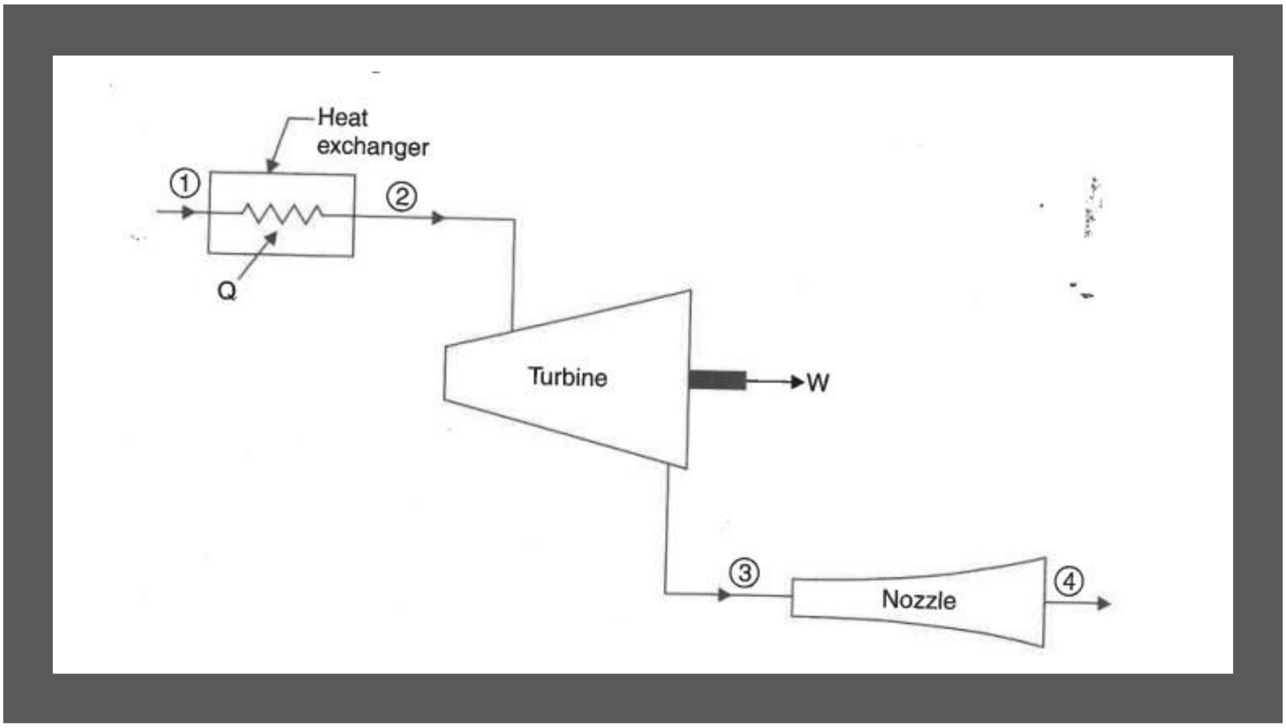
1. Air at 20°C passes through a heat exchanger at a velocity of 40m/s where its temperature rises to 820°C. It then enters a turbine with same velocity and expands till the temperature falls to 620C. On leaving the turbine, the air is taken at a velocity of 55 m/s to a nozzle where it expands until the temperature has fallen to 510°C. If the air flow rate is 2.5 kg/s, calculate:

1.1. Rate of heat transfer to the air in the heat exchanger

1.2. The power output from the turbine assuming no heat loss

1.3. The velocity at exit from the nozzle, assuming no heat loss

1.4. Take the enthalpy of air $h=C_pT$, where $C_p = 1.005$ kJ/kg°C



(RAJPUT, 2015)

(18 marks)

2. 0.3kg of Nitrogen gas at 100 kPa and 40^{o}C is contained in a cylinder. The piston is moved compressing Nitrogen until the pressure becomes 1 MPa and temperature becomes 160^{o}C. The work done during the process is 30 kJ. Calculate the heat transferred from the N_2 to the surroundings. c_v for nitrogen= 0.75 kJ/kg^{o} K

(Rajput 2015)

(6 marks)

3. A vessel having volume of 0.6 m^3, contains 3kg of liquid water and water vapour mixture in equilibrium at a pressure of 0.5 MPa, Calculate,

(a) mass and volume of liquid

(b) mass and volume of dry vapour

(Rajput 2015)
(6 marks)

References

- Rajput, R.K. (2015). Engineering Thermodynamics. Laxmi Publications (P) Ltd. New Delhi

Rajput (2015)

Absolute pressure (bar)	*Temp. (°C)*	*Specific enthalpy (kJ/kg)*			*Specific entropy (kJ/kg K)*			*Specific volume (m^3/kg)*	
p	t_s	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g	v_f	v_g
2.0	120.2	504.7	2 201.6	2 706.3	1.530 1	5.596 7	7.126 8	0.001061	0.885
2.1	121.8	511.3	2 197.2	2 708.5	1.546 8	5.563 7	7.110 5	0.001062	0.846
2.2	123.3	517.6	2 193.0	2 710.6	1.562 7	5.532 1	7.094 9	0.001064	0.810
2.3	124.7	523.7	2 188.9	2 712.6	1.578 1	5.501 9	7.080 0	0.001065	0.777
2.4	126.1	529.6	2 184.9	2 714.5	1.592 9	5.472 8	7.065 7	0.001066	0.746
2.5	127.4	535.3	2 181.0	2 716.4	1.607 1	5.444 9	7.052 0	0.001068	0.718
2.6	128.7	540.9	2 177.3	2 718.2	1.620 9	5.418 0	7.038 9	0.001069	0.693
2.7	129.9	546.2	2 173.6	2 719.9	1.634 2	5.392 0	7.026 2	0.001070	0.668
2.8	131.2	551.4	2 170.1	2 721.5	1.647 1	5.367 0	7.014 0	0.001071	0.646
2.9	132.4	556.5	2 166.6	2 723.1	1.659 5	5.342 7	7.002 3	0.001072	0.625
3.0	133.5	561.4	2 163.2	2 724.7	1.671 6	5.319 3	6.990 9	0.001074	0.606
3.1	134.6	566.2	2 159.9	2 726.1	1.683 4	5.296 5	6.979 9	0.001075	0.587
3.2	135.7	570.9	2 156.7	2 727.6	1.694 8	5.274 4	6.969 2	0.001076	0.570
3.3	136.8	575.5	2 153.5	2 729.0	1.705 9	5.253 0	6.958 9	0.001077	0.554
3.4	137.8	579.9	2 150.4	2 730.3	1.716 8	5.232 2	6.948 9	0.001078	0.538
3.5	138.8	584.3	2 147.4	2 731.6	1.727 3	5.211 9	6.939 2	0.001079	0.524
3.6	139.8	588.5	2 144.4	2 732.9	1.737 6	5.192 1	6.929 7	0.001080	0.510
3.7	140.8	592.7	2 141.4	2 734.1	1.747 6	5.172 9	6.920 5	0.001081	0.497
3.8	141.8	596.8	2 138.6	2 735.3	1.757 4	5.154 1	6.911 6	0.001082	0.486
3.9	142.7	600.8	2 135.7	2 736.5	1.767 0	5.135 8	6.902 8	0.001083	0.473
4.0	143.6	604.7	2 133.0	2 737.6	1.776 4	5.117 9	6.894 3	0.001084	0.462
4.2	145.4	612.3	2 127.5	2 739.8	1.794 5	5.083 4	6.877 9	0.001086	0.441
4.4	147.1	619.6	2 122.3	2 741.9	1.812 0	5.050 3	6.862 3	0.001088	0.423
4.6	148.7	626.7	2 117.2	2 743.9	1.828 7	5.018 6	6.847 3	0.001089	0.405
4.8	150.3	633.5	2 112.2	2 745.7	1.844 8	4.988 1	6.832 9	0.001091	0.390
5.0	151.8	640.1	2 107.4	2 747.5	1.860 4	4.958 8	6.819 2	0.001093	0.375
5.2	153.3	646.5	2 102.7	2 749.3	1.875 4	4.930 6	6.805 9	0.001094	0.361
5.4	154.7	652.8	2 098.1	2 750.9	1.889 9	4.903 3	6.793 2	0.001096	0.348
5.6	156.2	658.8	2 093.7	2 752.5	1.904 0	4.876 9	6.780 9	0.001098	0.337
5.8	157.5	664.7	2 089.3	2 754.0	1.917 6	4.851 4	6.769 0	0.001099	0.326

Felder et al. (2017)

THE GAS CONSTANT (R)

8.314 $m^3 \cdot Pa/(mol \cdot K)$
0.08314 $L \cdot bar/(mol \cdot K)$
0.08206 $L \cdot atm/(mol \cdot K)$
62.36 $L \cdot mm\ Hg/(mol \cdot K)$
0.7302 $ft^3 \cdot atm/(lb\text{-}mole \cdot {}^\circ R)$
10.73 $ft^3 \cdot psia/(lb\text{-}mole \cdot {}^\circ R)$
8.314 $J/(mol \cdot K)$
1.987 $cal/(mol \cdot K)$
1.987 $Btu/(lb\text{-}mole \cdot {}^\circ R)$

Felder et al. (2017)

FACTORS FOR UNIT CONVERSIONS

Quantity	Equivalent Values
Mass	$1\text{ kg} = 1000\text{ g} = 0.001\text{ metric ton (tonne)} = 2.20462\text{ lb}_m = 35.27392\text{ oz}$ $1\text{ lb}_m = 16\text{ oz} = 5\times10^{-4}\text{ ton} = 453.593\text{ g} = 0.453593\text{ kg}$
Length	$1\text{ m} = 100\text{ cm} = 1000\text{ mm} = 10^6\text{ microns }(\mu\text{m}) = 10^{10}\text{ angstroms (Å)}$ $= 39.37\text{ in} = 3.2808\text{ ft} = 1.0936\text{ yd} = 0.0006214\text{ mile}$ $1\text{ ft} = 12\text{ in} = 1/3\text{ yd} = 0.3048\text{ m} = 30.48\text{ cm}$
Volume	$1\text{ m}^3 = 1000\text{ L} = 10^6\text{ cm}^3 = 10^6\text{ mL} = 35.3145\text{ ft}^3$ $= 219.97\text{ imperial gallons} = 264.17\text{ gal} = 1056.68\text{ qt}$ $1\text{ ft}^3 = 1728\text{ in}^3 = 7.4805\text{ gal} = 29.922\text{ qt} = 0.028317\text{ m}^3 = 28.317\text{ L}$
Density	$1\text{ g/cm}^3 = 1000\text{ kg/m}^3 = 62.43\text{ lb}_m/\text{ft}^3$ = density of liquid water at 4°C (reference for specific gravities)
Force	$1\text{ N} = 1\text{ kg}\cdot\text{m/s}^2 = 10^5\text{ dynes} = 10^5\text{ g}\cdot\text{cm/s}^2 = 0.22481\text{ lb}_f$ $1\text{ lb}_f = 32.174\text{ lb}_m\cdot\text{ft/s}^2 = 4.4482\text{ N} = 4.4482\times10^5\text{ dynes}$
Pressure	$1\text{ atm} = 1.01325\times10^5\text{ N/m}^2\text{ (Pa)} = 101.325\text{ kPa} = 1.01325\text{ bar}$ $= 1.01325\times10^6\text{ dynes/cm}^2 = 14.696\text{ lb}_f/\text{in}^2\text{ (psi)}$ $= 760\text{ mm Hg at }0°\text{C (torr)} = 10.333\text{ m }H_2O(l)\text{ at }4°\text{C}$ $= 29.921\text{ inches Hg at }0°\text{C} = 406.8\text{ inches }H_2O(l)\text{ at }4°\text{C}$
Energy	$1\text{ J} = 1\text{ N}\cdot\text{m} = 10^7\text{ ergs} = 10^7\text{ dyne}\cdot\text{cm} = 1\text{ kg}\cdot\text{m}^2/\text{s}^2$ $= 2.778\times10^{-7}\text{ kW}\cdot\text{h} = 0.23901\text{ cal} = 0.23901\times10^{-3}\text{ kcal (food calorie)}$ $= 0.7376\text{ ft}\cdot\text{lb}_f = 9.486\times10^{-4}\text{ Btu}$
Power	$1\text{ W} = 1\text{ J/s} = 1\text{ N}\cdot\text{m/s} = 0.23901\text{ cal/s} = 0.7376\text{ ft}\cdot\text{lb}_f/\text{s}$ $= 9.486\times10^{-4}\text{ Btu/s} = 1.341\times10^{-3}\text{ hp}$