UNIVERSITY OF
LINCOLN
UNITED KINGDOM

College of Science
School of Engineering

Time Constrained Assessment

Module Title	**Energy Systems and Conversion**
Module Code	**EGR3030**
Module Coordinator	**Dr Ali Aliyu**
Duration of Assessment	**4 hours**
Date	**XX/12/2023**
Release Time	**09:00 - British Summer Time (BST)**
Submission Time	**13:00 - British Summer Time (BST)**

General Instructions to Candidates.

1. You **must** submit your answers to TurnItIn on Blackboard **before** the submission time: failure to do so will be classified as misconduct in examinations. It is strongly recommended you submit at least 15 minutes prior to the deadline.
2. You **must** also send a copy of your work to: soesubmissions@lincoln.ac.uk at the same time. You must place the Module Code and your Student ID in the Subject Field of the Mail.
3. For students who choose to word process their answers, hand-written notes or diagrams **must** be photographed (preferably using Microsoft Lens which is available as part of your Office 365 package) and inserted into the Word Document as an image.
4. This assessment is an open resource format: you may use online resources, lecture and seminar notes, text books and journals. All sources must be correctly attributed or referenced.
5. All work will be subject to plagiarism and academic integrity checks. In submitting your assessment, you are certifying that this is entirely your own work, without input from either commercial or non-commercial writers or editors, or advanced technologies such as Artificial Intelligence services. If standard checks suggest otherwise, Academic Misconduct Regulations will be applied.
6. The duration of the Time Constrained Assessment will vary for those students with Personalised Academic Study Support (PASS) plan. Extensions do not apply, but Extenuating Circumstances can be applied for in the normal way.

Module Specific Instructions to Candidates

1. Answer any 4 questions.
2. All questions carry equal marks.
3. No further marks will be awarded for answers to a fifth question
4. Useful equations are given in the Appendix
5. Thermodynamic tables uploaded in the Blackboard content for this module may be used

Question 1

a. What are the main sources of losses that prevent a wind turbine from operating at or near the Betz limit? [5 marks]

b. An engineer boasting about the virtues of their new wind turbine claimed it has an efficiency of 65.3%. Starting from $P=\frac{1}{2}m\left(v_1^2-v_2^2\right)$, with P being the power output resulting from a change in wind velocity from v_1 to v_2 across turbine's blades, show that the engineer's claim cannot be true and his efficiency value is in fact overestimated by at least 6 percentage points. [10 marks]

c. A horizontal axis wind turbine (HAWT) has a blade span (diameter) of 15 m and the hub is 35 m above ground level. The wind speed at 2 m height is 5 m/s.
   i. Calculate the actual power output of the wind turbine assuming maximum efficiency. [5 marks]
   ii. A wind turbine salesman while marketing their wind turbine claimed that with the dimensions above and at 50 m height, it can produce 250 kW power at 5 m/s wind speed (this wind speed is at 2 m height from the ground). Is the claim true? [5 marks]

[Total: 25 marks]

[End of Question 1]

Question 2

a. i. Name two differences between an Otto and a Diesel Cycle. [2 marks]
   iii. which is worse – putting petrol in a diesel engine or vice versa? Rationalise each scenario. [3 marks]

b. A gas turbine operating on the Brayton gas cycle has one each of isentropic compression and expansion. Air is taken into the compressor at 95 kPa and ambient temperature of 22ºC. The compressor has a ratio of 6 to 1 while the compressed air is heated to 827ºC. The combustion products then go through expansion in a turbine.
   i. Draw an annotated schematic and the T-S diagram for this cycle matching the numbering of each stream or process [5 marks]
   ii. Compute the thermal efficiency of the cycle. [10 marks]
   iii. Discuss the result above with respect to the compressor work and total turbine work. Your discussion should touch on what should be maximised and what should be minimised to ensure the economic viability of gas turbines. [5 marks]

[Note that interpolation from thermodynamic tables is required to obtain accurate results in this task]

[Total: 25 marks]

[End of question 2]

Question 3

a. i. What is Stoichiometric air? [2 marks]

ii. What is meant by lean and rich fuel mixtures? State an advantage and a disadvantage of an engine running on either. [8 marks]

b. A gaseous fuel (C_8H_{18}) is burned in the presence of air that is assumed completely dry. Volumetric analysis of the gaseous products on a dry basis revealed the following composition:

Carbon dioxide	10%
Oxygen	5.6%
Carbon monoxide	0.9%
Nitrogen	83.5%

i. Calculate the air–to–fuel ratio [5 marks]
ii. What is the percentage of theoretical air used, and [5 marks]
iii. Determine the quantity of water vapour that condenses as the products are cooled to 25°C at atmospheric pressure. [5 marks]

Note: you may take atmospheric pressure to be 10^5 Pa.

[Total: 25 marks]

[End of question 3]

Question 4

An adiabatic steam turbine has a power output 5.5 MW. The inlet and the exit conditions of the steam are as indicated in Figure 1.

a. Compare the magnitudes of changes in its enthalpy, potential, and kinetic energies. [8 marks]
b. Calculate the work done/mass of steam flowing within the turbine. [5 marks]
c. determine the mass flow rate of steam through the turbine. [2 marks]
d. With the aid of (two) schematics, explain why a cogeneration system will be more suited for district heating than a combined cycle system. [10 marks]

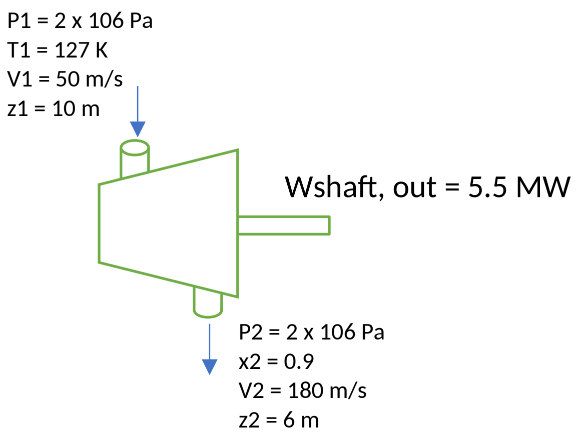

Figure 1: Steam turbine schematic for Question 4a-c

[Total: 25 marks]

[End of question 4]

Question 5

a. Exergy and energy are very important quantities in the analysis and design of new power generation systems. As a junior engineer, a student on placement came to you with a question as they would like to know the difference between the two. Give them 3 differences, using equations where necessary. [6 marks]

b. Starting with energy and entropy balances, show that the general exergy balance for a closed system operating between two states 1 and 2 can be expressed as:

$$X_2 - X_1 = \int_1^2 \left(1 - \frac{T_o}{T_b}\right) \delta Q - \left[W - P_o \left(V_2 - V_1\right)\right] - T_o S_{gen}$$

[6 marks]

c. A small scall model car is powered by a hydrogen fuel cell that operates at 25°C and a pressure of 100 kPa, using pure hydrogen and oxygen from ambient air. The partial pressure of the water resulting from the hydrogen and oxygen is 30 kPa.

   i. What is the potential drop across the fuel cell? [5 marks]

   ii. If the air is replaced with pure oxygen, assuming everything else remains the same, what is the new potential across its terminals? [8 marks]

[Total: 25 marks]

[End of question 4]

Appendix

Power law wind velocity profile $U(z) = U(z_r)\left(\frac{z}{z_r}\right)^a$ where $a = 0.2$.

Heat balance: $m_{valve.\in¿} h_{valve.\in¿} + m_{t.\in¿} h_{t.\in¿} = m_{out} h_{out} + Q_p ¿¿¿¿$

Non-flow energy equation (NFEE)

$$\delta q = du + pdv, \delta w = pdv : absoulte\ work$$

Steady-flow energy equation (SFEE) in the case where kinetic and potential energy are negligible

$$\delta q - \delta w_s = dh, \delta w_s = -vdp : shaft\ work$$

Enthalpy	$h \equiv u + Pv$
Two-phase mass average	$u = u_f + x(u_g - u_f)$
	$h = h_f + x(h_g - h_f)$
	$s = s_f + x(s_g - s_f)$
Ideal gas	$h = u + Pv = u + RT$
	$c_v = \left(\frac{du}{dT}\right)_v, c_p = \left(\frac{dh}{dT}\right)_p = c_v + R$
Thermal efficiency	$\eta_{th} = \frac{network}{heat\ input} = \frac{w_{net}}{q_{in}}$
Coefficient of performance	$COP = \frac{amout\ of\ heat\ absorved\ to\ system}{amout\ of\ work\ required\ to\ system} = \frac{q_L}{w_{in}}$
Isentropic efficiency	$\eta_t = \frac{actual\ turbne\ work}{ideal\ turbine\ workt} = \frac{w_t}{w_{t'}}\ for\ turbine$
	$\eta_c = \frac{ideal\ compressor\ work}{actual\ compressor\ workt} = \frac{w_{c'}}{w_c}\ for\ compressor$
	$\eta_{fp} = \frac{ideal\ pump\ work}{actual\ pump\ workt} = \frac{w_{fp'}}{w_{fp}}\ for\ pump$
Interpolation	$y = y_1 + (y_2 - y_1)\left(\frac{x - x_1}{x_2 - x_1}\right)$

Subscripts

f	property of saturated liquid
g	property of saturated vapour

[End of Time Constrained Assessment]