

The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

A LEVEL 4 MODULE, SPRING SEMESTER 2016-2017

ADVANCED THERMAL POWER SYSTEMS

Time allowed ONE Hour and THIRTY Minutes

Candidates may complete the front cover of their answer book and sign their desk card but must NOT write anything else until the start of the examination period is announced

Answer ALL questions in Section A and TWO questions in Section B

Only silent, self-contained calculators with a Single-Line Display or Dual-Line Display are permitted in this examination.

Dictionaries are not allowed with one exception. Those whose first language is not English may use a standard translation dictionary to translate between that language and English provided that neither language is the subject of this examination. Subject specific translation dictionaries are not permitted.

No electronic devices capable of storing and retrieving text, including electronic dictionaries, may be used.

DO NOT turn the examination paper over until instructed to do so

In this examination candidates are required to answer ALL questions in Section A and TWO out of FOUR questions in Section B. If a candidate answers more than the required number of questions, all questions will be marked and the highest will be used in the final examination mark.

ADDITIONAL MATERIAL: Formula sheet
 Tables of Thermodynamic Properties of Fluids
 Enthalpy-entropy chart for Steam

INFORMATION FOR INVIGILATORS:

Question papers should be collected in at the end of the exam – do not allow candidates to take copies from the exam room.

Turn Over

SECTION A

ANSWER ALL QUESTIONS IN THIS SECTION

It should not be necessary to write more than about two or three sentences in answer to any part of this question. All parts carry equal.

1. For a stoichiometric mixture of nitrogen and oxygen to form nitric oxide (NO), at what temperature do you expect that we can get 0.1% NO in the gas mixture?
2. Demonstrate by using the data tables how the difference between formation enthalpy of water in the liquid and vapour phases arises.
3. Demonstrate how the non-steady-flow energy equation can be reduced to an exact 4 term formula for a perfectly insulated, rigid tank of compressed air discharging through a turbine. Assume kinetic energy is negligible.
4. Vapour power cycles often include a deaerator in the circuit. What are the two main benefits of doing this?
5. Briefly describe the meaning of approach temperature and pinch point in a heat recovery steam generator.
6. A steam turbine generator receives superheated steam with enthalpy 3200 kJ/kg and exhausts to a condenser with enthalpy 2300 kJ/kg. If the mechanical efficiency of the generator is 95%, calculate the specific irreversibility.
7. Briefly describe the operational principles of oxy-fuel combustion for power generation, outlining the main costs and benefits.
8. Describe briefly why uranium-238 is the most available source of energy production by fission reactions and why it must be refined to produce an effective reactor core.
9. Briefly describe the control mechanisms available for a BWR reactor.
10. Calculate the speed of a neutron with a kinetic energy of 0.4 MeV.

SECTION B

ANSWER TWO OUT OF FOUR QUESTIONS IN THIS SECTION

11. A gasifier relies on the water-gas shift reaction: $\text{H}_2 + \text{CO}_2 \rightarrow \text{H}_2\text{O} + \text{CO}$.

- (a) Show that the equilibrium constant is related to the dissociation of
- CO_2
- ,
- α
- , by the expression:

$$\frac{\alpha^2 + 1 + 2\alpha}{\alpha^2}$$

Demonstrating what happens to the pressure term. [10]

- (b) The desired gas mixture is produced when there is 50% dissociation, in order to give equal amounts of H_2 and CO . Determine the temperature that this will occur at in a reaction vessel at 1 bar. Explain what you expect to happen at 20 bar. [15]
- (c) Calculate the energy of reaction per kmol of H_2 in the reactor vessel to cause this dissociation. [10]

12. A gas turbine has a pressure ratio of 10.5, with inlet conditions 300K and 1 atm. The fuel is methane and reaches adiabatic flame temperature with 60% excess air by volume. The polytropic efficiency of the compressor and turbine are both 90%. There pressure losses in the inlet, combustion chamber and exhaust of 0.01325, 0.5, and 0.02 bar respectively. The mass flow rate of air is 9 kg/s.

- (a) Calculate the compressor exit temperature and verify that 2000K is a reasonable turbine entry temperature estimate.

Assume a mean c_p of exhaust gases between 300K and 2000K of 1.319 kJ/kgK. The mass of the exhaust gases per kmol of fuel may be assumed to be 454 kg without calculation. [10]

- (b) Calculate the cycle efficiency and specific work output, assuming the mass flux of fuel is negligible.

Assume the mean c_p of the compressor air is 1.005 kJ/kgK. [13]

- (c) Calculate the mass flow rate of fuel and briefly discuss whether it is reasonable to regard it as negligible. [10]

Turn over

- 13.** A supercritical steam power plant produces steam at 350 bar and 700°C. Three expansion turbines are used:
- the high pressure turbine has 90% isentropic efficiency and reduces to 90 bar, where a fraction is bled to a closed feed-heater prior to reheating the remainder up to 700°C;
 - the intermediate pressure turbine has a 95% isentropic efficiency and outlet pressure of 20 bar, where a further fraction is bled to an open feedheater;
 - the low pressure turbine has an isentropic efficiency of 90%, and exhausts at 0.07 bar.

In the closed feed heater, the feedwater is heated to 270°C, and the condensed steam leaves as water at 250°C, and is throttled into the open feedheater. In the open feedheater, the feedwater is heated to 150°C. The pump work may be considered to be negligible.

- At each point in the cycle find the enthalpy and entropy and the proportion of bled steam to each feed heater. [17]
- Calculate the exergy into each turbine and the exergy destroyed in the condenser and comment on the energy and exergy lost in the condenser. [16]

Steam chart accuracy is sufficient. The environmental condition is 15°C saturated water.

- 14.**
- Compare the energy in eV of a single atom of carbon combusting to CO₂ with the energy of a thermal neutron. [8]
 - Calculate the deBroglie wavelength of a thermal neutron and describe how this determines its interaction with a nucleus. [6]
 - Explain fission product yield and how some daughter nuclides give rise to the useful properties of delayed fission, and describe how this affects reactor stability. [10]

END