The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

A LEVEL 4 MODULE, SPRING SEMESTER 2017-2018

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 marks 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 question in Section A. All questions carry equal marks, with a total of 30 marks for Section A.

1. State from the tables the value of Gibbs free energy for water vapour at 300K. In calculating the Equilibrium constant for reactions with water, what further consideration is required for the Gibbs free energy?

2. Calculate the specific entropy of carbon dioxide at 600K and 20 bar.

3. Demonstrate how the non-steady-flow energy equation can be reduced to an exact 3 term formula for an uninsulated, rigid tank of compressed air discharging slowly <u>through a throttle valve</u> , as indicated in Figure Q3, to the atmosphere, in which kinetic and potential effects are negligible.

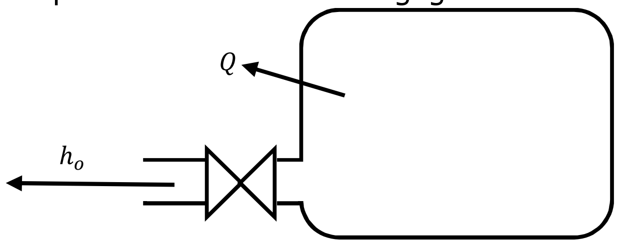

Figure Q. 3

4. Briefly describe three features of Organic Rankine cycles that distinguish them from steam cycles.

5. A boiler is fired by hot gases with an ingoing flow exergy of 4MW and exhaust exergy of 0.7MW. It powers a steam turbine which receives steam with flow exergy going in of 3MW and the steam finally condenses, going out with flow exergy of 0.5MW. The condensed water from the turbine passes directly to the boiler as feedwater. Calculate the irreversibility of the boiler.

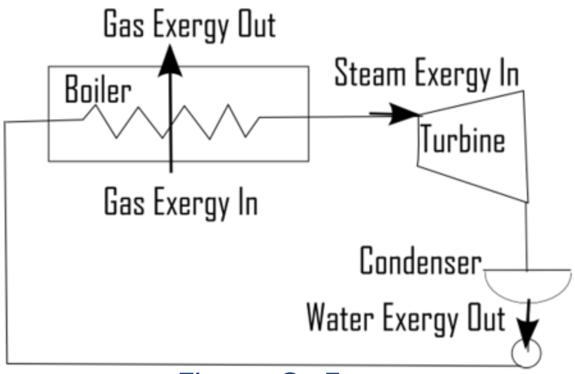

Figure Q. 5

6. Briefly describe the benefits of feed heating in a Rankine cycle, and further, the implications of using feed heating in a heat recovery steam generator application.

7. For a centrifugal gas compressor with isentropic efficiency of 90% at a pressure ratio of 8, calculate the polytropic efficiency for air with $\gamma = 1.4$.

8. Briefly describe the function of moderation in nuclear power generation.

9. A typical thermal neutron has a deBroglie wavelength in the order of 10^{-10}m. Comment on the order of magnitude.

10. Calculate the speed of a neutron with a kinetic energy of 0.1 MeV.

SECTION B

ANSWER TWO OUT OF FOUR QUESTIONS IN THIS SECTION

11. (a) By determining Gibbs function from entropy and enthalpy, calculate the equilibrium constant for the following reaction at 1400K:

$$\frac{1}{2}N_2 + \frac{1}{2}O_2 \leftrightarrow NO$$

[20]

(b) State the effect on equilibrium constant of altering the system pressure, and describe the influence on mixture composition. [15]

12. A gas turbine operates in an environment in ambient conditions -2°C and 985 mbar. The combustion chamber is at an average of 13.9 bar and the turbine inlet temperature is 1380°C. The turbine isentropic efficiency of compressor and turbine are both 88% and the mean specific heat capacity and adiabatic index are 1.004 kJ/kgK and 1.4 in the compressor and 1.254 kJ/kgK and 1.297 in the turbine.

(a) Calculate the compressor and turbine outlet temperatures. [10]

(b) Determine the cycle efficiency. [15]

(c) What thermal management approaches might be taken to improve work output or efficiency? [10]

13. A solar thermal tower power plant uses a molten salt (c_p = 3.2 kJ/kgK and mass flow rate 22.7kg/s) to transfer heat from the solar tower to the steam cycle in a heat recovery steam generator. The salt temperature at inlet to the heat exchanger is 550°C. The steam cycle attached to the HRSG operates at 30 bar. The pinch temperature difference is 8°C and the approach temperature difference is 70°C. The water at inlet to the economiser is at 40.3°C.

(a) Calculate the mass flow rate of steam in the cycle. [18]

(b) Calculate the relative areas of the economiser, evaporator and superheater heat exchangers. [17]

Steam chart accuracy is sufficient.

14. (a) Explain with the aid of a diagram the meaning of fission product chain yield for binary nuclear fission. [10]

(b) Explain the meaning of a thermal neutron and comment on the interaction behaviour with atomic nuclei. [10]

(c) A ^{235}U (atomic mass 235.043 923 1u) nucleus undergoes interaction with a thermal neutron to produce $^{140}_{54}Xe$ (atomic mass 136.911 563u) and $^{93}_{38}Sr$ (atomic mass 92.914 022) with the associated release of three neutrons. Calculate the energy release and explain how this is dissipated. [15]

END