# The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

A LEVEL 3 MODULE, AUTUMN 2016-2017

**ENERGY EFFICIENCY FOR SUSTAINABILITY 2**

Time allowed ONE Hour and THIRTY Minutes

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*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 parts of QUESTION ONE and TWO OTHER questions***

*Only silent, self contained calculators with a Single-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 examination paper over until instructed to do so***

***In this examination candidates are required to answer Question 1 and two of the remaining questions. 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:** 4 page formula booklet
Tables of Thermodynamic and Transport Properties of Fluids
Enthalpy/Entropy chart for steam
8 page answer book.

**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*

1. Answer each part of this question. Each part carries the same mark.
*It should not be necessary to write more than about two or three sentences in answer to any part of this question.*

(a) List the three fuels that globally provide the most primary energy.

(b) List three greenhouse gases that contribute the most to climate change.

(c) Give two examples of features in a building that contribute to passive solar design.

(d) State two advantages of using gasification for energy production from coal.

(e) Heat flows at a rate of 6 MW and at a temperature of 350°C into a power plant. If the ambient temperature is 17°C, what is the maximum possible electrical power output from plant?

(f) An electric shower has a water flow rate of 12 litres/minute. If the cold water inlet is at a temperature of 10°C and the hot water leaving the shower is at a temperature of 40°C, what is the electric power input required?

(g) Define exergy.

(h) Give examples of three different irreversible processes in pieces of equipment.

(i) What would an energy manager use *degree days* for?

(j) Why is it advantageous to use a heat pump to provide space heating for a building?

[Total 30 marks]

2. Describe, with the aid of a diagram, the processes involved in the combustion of a solid fuel. [10]

Describe the ways in which incomplete combustion of a solid fuel can lead to emissions of pollution from a combustion plant. Describe the nature of the pollution and the harm that it can do. Explain. [15]

Explain how incomplete combustion can be avoided in a solid fuelled process. [10]

3. Methane (gross calorific value of 55640 kJ/kg) is used as a fuel for an industrial heat treatment furnace. The air/fuel ratio gives 100% excess air. The exhaust gases from the furnace leave at 300°C. The ambient temperature at which the gas and air enter the furnace is 15°C.

(a) Calculate the volumetric composition of the products of combustion. [10]

(b) A heat exchanger is installed to recover heat from the exhaust gases and preheat the combustion air. If the combustion air is preheated to 250°C calculate the gas flow rate required to give a heat input to the furnace of 2.5 MW. Assume that the air/fuel ratio does not change. [18]

(c) Suggest two ways in which the combustion efficiency of the furnace could be increased. [7]

In all calculations, use specific heat capacity of dry gases at a temperature of 400K. State any assumptions that you make.

4. In a power generation system, steam at a temperature of 50 bar and 450°C and a flow rate of 10 kg/s is throttled to 10 bar and then enters a steam turbine that exhausts at a pressure of 0.5 bar where the steam is condensed in a condenser and the heat is dissipated to the environment. The steam turbine has an isentropic efficiency of 85% and it drives a generator with an efficiency of 94%. The condensed water leaves the condenser at 81.3°C and returns to a boiler.

The environment temperature is 0°C.

(a) Draw a diagram of the process labelling the flows. [5]

(b) Calculate the electricity output from the generator. [8]

(c) Calculate the exergy in the steam and water flows, the losses in exergy (irreversibilities) in each part of the system and the overall rational efficiency of this power generating system. [12]

(d) Comment on the irreversibilities, explain how they could be reduced and what the consequences would be. [10]

Use steam chart for properties of steam.

Assume that the enthalpy and entropy of water are both zero at the environment temperature of 0°C.

*Turn Over*

5. A new heating system is installed in a retail warehouse. Two heating systems A and B are under consideration:

System A is a warm air system in which all of the heat input is as warm air. System B is a radiant heating system in which there is a high proportion of radiant heating and where the heat input can be represented as being entirely at the *environmental point* in the building.

A *dry resultant* (or *comfort*) *temperature* of 17°C is required in the building.

(a) Calculate the heat input required from each of the two heating systems. [27]

(b) Which of the heating systems requires the lower heat input to maintain the building at the required comfort level? Explain why this is. [8]

The following data are given:

The outside temperature is -1°C
The fabric heat loss from the building is given by:

$$Q_F = 2000\,(T_e - T_o) \text{ Watts}$$

Where: $T_e$ (°C) is the environmental temperature inside the building and
$T_o$ (°C) is the outside temperature.

The ventilation heat loss from the building is given by:

$$Q_v = 4000\,(T_a - T_o) \text{ Watts}$$

Where: $T_a$ (°C) is the air temperature inside the building.

Heat transfer between the dry resultant point and the environmental point in the building is given by:

$$Q_{ce} = 120000\,(T_c - T_e) \text{ Watts}$$

Where: $T_c$ (°C) is the dry resultant temperature inside the building

Heat Transfer between the dry resultant point and the air point in the building is given by:

$$Q_{ca} = 40000\,(T_c - T_a) \text{ Watts}$$

**END**