UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For the following qualifications :-

B.Eng. *M.Eng.* *M.Sc.*

Chemical Eng E808: Thermodynamics

COURSE CODE	:	**CENGE808**
UNIT VALUE	:	**0.50**
DATE	:	**15-MAY-02**
TIME	:	**10.00**
TIME ALLOWED	:	**3 hours**

02-C0178-3-90

TURN OVER

*Answer **FOUR** questions only.*
Each question carries a total of 25 marks distributed as shown [ ].

1. a) With the aid of simple, clearly labelled diagrams describe what is meant by a 'Closed', 'Isolated' and 'Open' system in the context of thermodynamics. [4]

   b) Define what is meant by a 'State Function' and whether heat, work and internal energy are State Functions. [3]

   c) Using an example of a gas confined in a piston and cylinder arrangement, state three important conditions that have to be fulfilled in order for the gas to produce the maximum amount of work possible following the application of heat. [3]

   d) Calculate the amount of work done by an ideal gas undergoing either a reversible or an irreversible expansion from an initial volume and pressure of 1 m^3 and 10 bara to a final pressure of 5 bara. You may ignore heat losses. Comment on the significance of your answer. [9]

   e) Starting with the equation for the first law of thermodynamics, derive the following expressions,

$$\Delta U = Q = \int_{T_2}^{T_1} C_v dT \quad \text{(for a constant volume process)}$$

$$\Delta H = Q = \int_{T_2}^{T_1} C_P dT \quad \text{(for a constant pressure process)}$$ [6]

TURN OVER

2. a) Draw a simple process flow diagram for a steam power plant operating on the basis of a Carnot cycle, carefully labelling all the important process components. With reference to the same diagram, draw the corresponding temperature/entropy diagram. [5]

b) A Carnot heat engine receives 500 kJ of heat from a high temperature heat source at 625 °C and rejects heat to a low-temperature sink at 30 °C. Determine

i) the thermal efficiency of this Carnot heat engine
ii) the amount of heat rejected to the sink [6]

c) Define what is meant by the Coefficient of Performance for a refrigerator. [2]

d) The interior lighting of refrigerators is provided by incandescent lamps whose switches are actuated by the opening of the refrigerator door. Consider a refrigerator whose 40 W light bulb remains switched on continuously as a result of a malfunction of the switch. If the refrigerator has a coefficient of performance of 1.3 and the cost of electricity is 8 pence per kWh, determine the increase in the energy consumption of the refrigerator and its cost per year (365 days) if the switch is not fixed. [12]

You may assume that the refrigerator is opened 20 times per day for an average of 30s on each occasion.

3. a) Draw a process flow diagram for a steam power plant operating on the basis of the ideal Rankine cycle. With reference to the same diagram, draw the corresponding/temperature entropy diagram. [10]

b) Consider a steam power plant operating on the basis of the ideal Rankine cycle. The steam enters the turbine at 30 bara and 350 °C and is condensed in the condenser at a pressure of 0.75 bara. Determine the thermal efficiency of this cycle. [15]

You may assume specific volume of condensed steam is 0.001 m^3/kg.

TURN OVER

4. Using the first law of thermodynamics for a closed system of constant composition and the defining equations for Helmotz free energy and Gibbs free energy, respectively given by

$$A = U - TS$$

$$G = H - TS$$

Show that

$$S = -\left(\frac{\partial A}{\partial T}\right)_V = -\left(\frac{\partial G}{\partial T}\right)_P$$
$$V = \left(\frac{\partial H}{\partial P}\right)_S = \left(\frac{\partial G}{\partial P}\right)_T$$
$$P = -\left(\frac{\partial A}{\partial V}\right)_T = -\left(\frac{\partial U}{\partial V}\right)_S$$
$$T = \left(\frac{\partial H}{\partial S}\right)_P = \left(\frac{\partial U}{\partial S}\right)_V$$

[25]

5. a) Draw a process flow diagram indicating the main components of a vapour compression refrigeration cycle. With the aid of the same figure, draw the corresponding T/S and P/H diagrams assuming the cycle operates on the basis of an ideal vapour compression refrigeration cycle. [10]

b) An ideal vapour compression refrigeration cycle uses ammonia as the working fluid operating at a condenser and evaporator pressure of 1.902 bara and 10.99 bara respectively. If the mass flow rate of the refrigerant is 0.05 kg/s, determine;

i) the rate of heat removal from the refrigerant and the power input into the compressor [5]

ii) the rate of heat rejection to the environment [5]

iii) the COP of the refrigerator [5]

TURN OVER

6. a) Express the defining equation for the Joule Thomson Coefficient in terms of a simple mathematical expression, carefully explaining the significance of the terms used and the prescribing conditions. [3]

b) What is the significance of the Joule Thomson Coefficient? [2]

c) Show that the Joule Thomson Coefficient is also given by

$$\eta = \frac{1}{C_p}\left[T\left(\frac{\partial V}{\partial T}\right)_p - V\right] \qquad [10]$$

You may use the Maxwell relation,

$$\left(\frac{\partial S}{\partial P}\right)_T = \left(-\frac{\partial V}{\partial T}\right)_p$$

d) Using the above expression, prove that η for an ideal gas is zero. Explain why one would necessarily expect to arrive at this answer. What does it tell you about the suitability of using an *ideal gas* as a refrigerant in a refrigeration system. [5]

e) Calculate η for a certain substance at 25 °C and 1bara for which C_p = 138 kJ/(kmolK) ,V = 0.09 m^3/kmol and $\left(\frac{\partial V}{\partial T}\right)_P = 9.0 \times 10^{-8}$ m^3/molK. [5]

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