JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY

SCHOOL OF ENGINEERING AND TECHNOLOGY

UNIVERSITY EXAMIMATION FOR THE DEGREE IN SCIENCE IN RENEWABLE ENERGY TECHNOLOGY AND MANAGEMENT

1ST YEAR 2ND SEMESTER 2023/2024 ACADEMIC YEAR

CENTRE: MAIN CAMPUS

COURSE CODE: TEB 1106

COURSE TITLE: HEAT AND THERMODYNAMICS

EXAM VENUE: **STREAM: BSc. REN ENGY TEC & MGT**

DATE: /04/2024 **EXAM SESSION:**

DURATION: 2 HOURS

Instructions

1. **Answer question 1 (Compulsory) and ANY other two questions**
2. **Candidates are advised not to write on question paper**
3. **Candidates must hand in their answer booklets to the invigilator while in the examination room.**

Question One (Compulsory)

a) A plane wall is 150mm and it wall area is $4.5m^2$. If it conductivity is $9.35 W/m^{\circ} C$ and surface temperature are steady at 150 and 45 determine the following. **(3 Marks)**

(i) Heat flow across the plane

(ii) Temperature gradient in the flow direction

b) Define the following terms used in thermodynamics systems. **(3 Marks)**

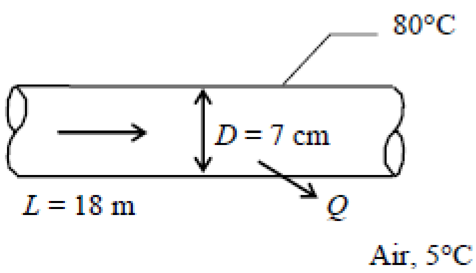
(i) State

(ii) Process

(iii) Cycle

c) Describe the difference between a heat engine and a reversed heat engine. **(2 Marks)**

d) A hot water pipe at 80°C is losing heat to the surrounding air at 5°C by natural convection with a heat transfer coefficient of 25 $W/m^2.°C$. Determine the rate of heat loss from the pipe by convection. **(3 Marks)**



e) Using illustrations state the following Laws **(4 Marks)**

(i) First Law of Thermodynamics:

(ii) Zeroth law of Thermodynamics

f) Define the following thermodynamic systems. **(6 marks)**

(i) Closed system:

(ii) Open system

(iii) Isolated system

(iv) Adiabatic system

g) Using well labelled diagrams discuss reversible and irreversible processes. **(4 Marks)**.

h) A piston and cylinder machine containing a fluid system has a stirring device as shown in Figure 1e. The piston is frictionless, and it is held down against the fluid due to atmospheric pressure of 101.3 kPa. The stirring device is turned 9500 revolutions with an average torque against the fluid of 1.25 Nm. Meanwhile the piston of 0.65 m diameter moves outn0.6 m. Find the network transfer for the system. **(5 Marks)**

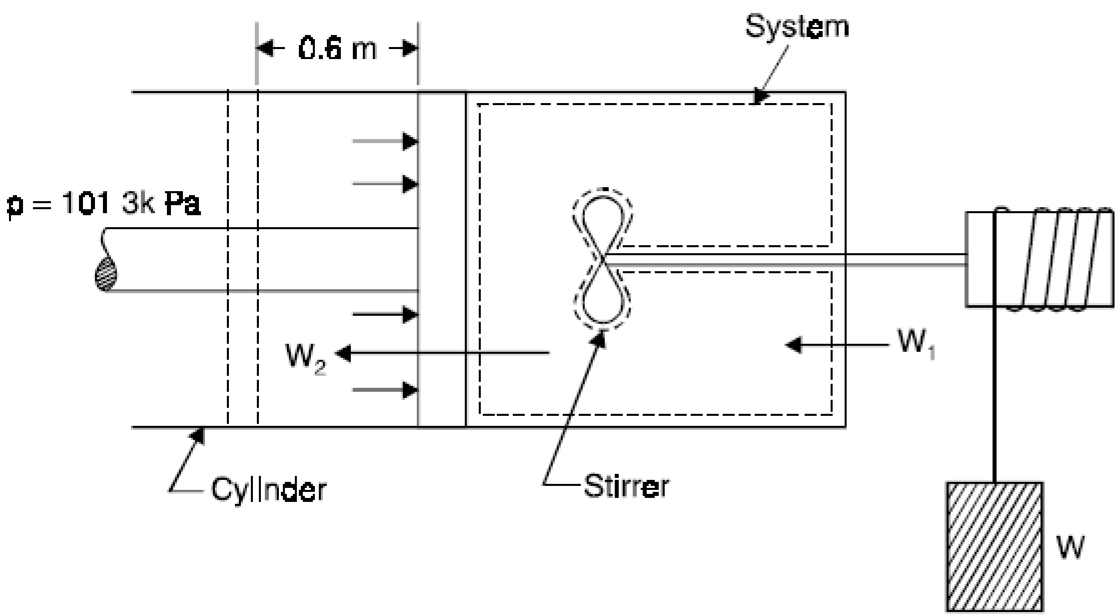


Figure 1e. piston and cylinder machine

QUESTION TWO

a) In an air compressor shown in figure 2b below air flows steadily at the rate of 0.5 kg/s through an air compressor. It enters the compressor at 6 m/s with a pressure of 1 bar and a specific volume of 0.85 m^3/kg and leaves at 5 m/s with a pressure of 7 bar and a specific volume of 0.16 m^3/kg. The internal energy of the air leaving is 90 kJ/kg greater than that of the air entering. Cooling water in a jacket surrounding the cylinder absorbs heat from the air at the rate of 60 kJ/s. Calculate the following**:** **(5 Marks)**

(i) The power required to drive the compressor;

(ii) The inlet and output pipe cross-sectional areas.

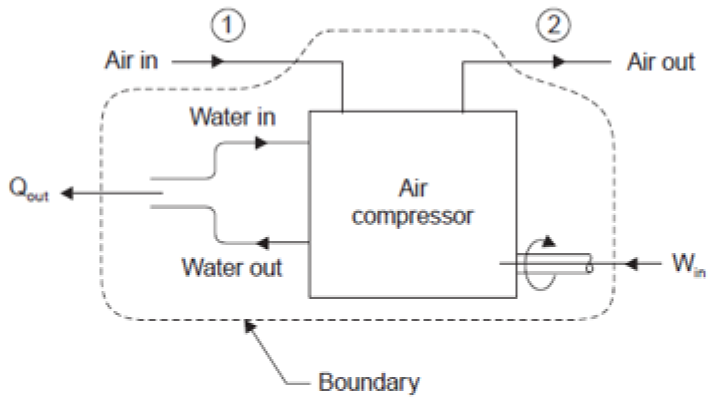


Figure 2b Air compressor

b) A closed system of constant volume experiences a temperature rise of 25°C when a certain process occurs. The heat transferred in the process is 30 kJ. The specific heat at constant volume for the pure substance comprising the system is 1.2 kJ/kg°C, and the system contains 2.5 kg of this substance. Determine **(10 Marks)**

i. The change in internal energy;
ii. The work done
iii. Indicate if the process is irreversible

c) Using a well labelled diagram discuss the working principle of a radiation pyrometers **(5 Marks)**

<u>QUESTION THREE</u>

a) Discuss the three modes of heat transfer. **(6 Marks)**

b) Evaluate the rate of heat transfer (Q_k) through a rectangular-plane wall of 0:1524 m thickness and thermal conductivity (K) of 0.432 W/m K under steady-state uniform surface temperatures of T_1 = 21:1 and T_2 = 71:1˚C. **(4 Marks)**

c) In an internal combustion engine, during the compression stroke the heat rejected to the cooling water is 50 kJ/kg and the work input is 100 kJ/kg. Calculate the change in internal energy of the working fluid stating whether it is a gain or loss. **(5 Marks)**

d) 0.3 kg of nitrogen gas at 100 kPa and 40°C is contained in a cylinder as shown in Figure 3b. The piston is moved compressing nitrogen until the pressure becomes 1 MPa and temperature becomes 160°C. The work done during the process is 30 kJ. **(5 Marks)**

Calculate the heat transferred from the nitrogen to the surroundings.

cv for nitrogen = 0.75 kJ/kg K.

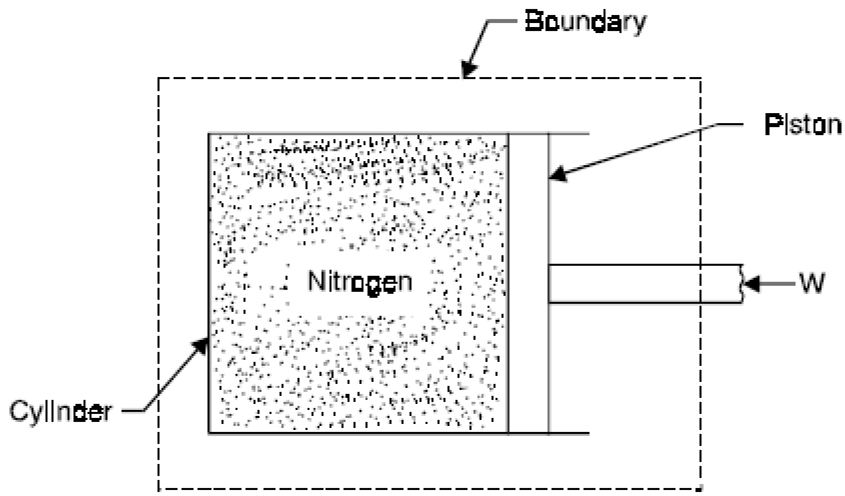


Figure 3b Piston

QUESTION FOUR

a) A cylinder contains 0.45 m^3 of a gas at 1×10^5 N/m2 and 80°C. The gas is compressed to a volume of 0.13 m^3, the final pressure being 5×10^5 N/m^2. Determine

(i) The mass of gas **(2 Marks)**

(ii) The value of index 'n' for compression **(3 Marks)**

(iii) The increase in internal energy of the gas **(3Marks)**

(iv) The heat received or rejected by the gas during compression **(4 Marks)**

Take $\gamma = 1.4$, R = 294.2 J/kg°C.

Initial volume of gas, $V_1 = 0.45$ m^3
Initial pressure of gas, $p_1 = 1 \times 10^5$ N/m^2
Initial temperature, $T_1 = 80 + 273 = 353$ K
Final volume after compression, $V_2 = 0.13$ m^3
The final pressure, $p_2 = 5 \times 10^5$ N/m^2.

b) A system consisting of 1 kg of an ideal gas at 5 bar pressure and 0.02 m^3 volume executes a cyclic process comprising the following three distinct operations: (i) Reversible expansion to 0.08 m^3 volume, 1.5 bar pressure, presuming pressure to be a linear function of volume (p = a

+ bV), (ii) Reversible cooling at constant pressure and (iii) Reversible hyperbolic compression according to law pV = constant. This brings the gas back to initial conditions.

(i) Sketch the cycle on p-V diagram. **(3 Marks)**

(ii) Calculate the work done in each process starting whether it is done on or by the system and evaluate the net cyclic work and heat transfer**. (5 Marks)**

<u>QUESTION FIVE</u>

a) State the Clausius and Kelvin Statements of the second law **(4 Marks)**

b) With illustrations discuss Perpetual motion machine PMM1 and PMM2 **(5 Marks)**

c) A Carnot cycle operates between source and sink temperatures of 250°C and – 15°C. If the system receives 90 kJ from the source, find : **(5 Marks**)

   i. Efficiency of the system;
   ii. The net work transfer;
   iii. Heat rejected to sink.

d) A cyclic heat engine operates between a source temperature of 1000°C and a sink temperature of 40°C. Find the least rate of heat rejection per kW net output of the engine **(6 Marks)**