LAIKIPIA UNIVERSITY

UNIVERSITY EXAMINATIONS

1ST SEMESTER 2022/2023 ACADEMIC YEAR

FIRST YEAR EXAMINATION FOR THE DEGREES OF BACHELOR OF EDUCATION (SCIENCE)/BACHELOR OF SCIENCE (GENERAL)

PHYS 113: HEAT AND THERMODYNAMICS

STREAM: R ***TIME: 2 HRS***

DAY: WED [8.30AM – 10.30AM] ***DATE: 07/12/2022***

THIS QUESTION PAPER CONSISTS OF FIVE (5) PAGES

PLEASE DO NOT OPEN UNTIL THE INVIGILATOR SAYS SO.

INSTRUCTIONS: - Answer question one Compulsory (40 marks) and any other two questions (15 marks each)

. Latent heat of fusion of water is 335KJ/Kg

Universal Gas constant is 8.314J/mol.K

Molar specific heat capacity of nitrogen gas, c_v = 20.8 J/mol/K

Stefan's constant, $\sigma = 5.67x10^{-8}W/m^2/K^4$

Molecular weight of Nitrogen (N_2) = 28g

QUESTION ONE

(a). Define the following terms

(i). Adiabatic process (1 mark)

(ii). Internal energy (1 mark)

(iii). Stefan's law of radiation (1 mark)

(iv). Ideal absorber (1 mark)

(v). Isothermal process (1 mark)

(b). Mention any four advantages of mercury as a thermometric fluid. (2 marks)

(c). Heat travels through three different mechanisms, explain them (3 marks)

(d). The surface temperature of a spherical metal of radius $4.5x10^5$m is 6000K.Calculate the total energy radiated by the body each second. (Assume emissivity of metal as 0.92.)

(4 marks)

(e).State the first law of thermodynamics (1 mark)

(f). (i) 1. 2g of ice at -30^0C (at one atmospheric pressure) is heated to steam. How much heat is required to change ice to superheated steam at 150^0? (3 marks)

(ii). State the classical statements of the second law. (2 marks)

(g). A cylinder contains a gas at 30°Cand a pressure of $15x10^3$Pa and a volume of 8 liters. The temperature of the gas is raised to 50°C and volume reduced to 6 liters. Find the final pressure of the gas. (Assume gas is ideal) (3 marks)

(h). State the Zeroth law of thermodynamics (2 marks)

(i). The New River Gorge Bridge in West Virginia is 518-m long steel arch. How much will its length change between temperature extremes of -20^{0}C and 35^{0}C? (Coefficient of linear expansion for steel is α =11X10^{-6}C^{-1}) (4 marks)

(j). Distinguish the following terms as used in heat and thermodynamics

i. Latent heat of vaporization and latent heat of fusion (2 marks)

ii. Condensation and boiling (2 marks)

iii. Freezing and melting (2 marks)

(k). An internal energy of a solid increased when the heat is transferred to it from its surroundings. A 1kg bar of copper is heated at atmospheric pressure. If its temperature is increased from 20^{0}C to 50^{0}C

i) Find the work done by copper (2 marks)
ii) What quantity of heat is transferred to the copper? (2 marks)
iii) What is the increase in internal energy of the copper? (1 marks)

QUESTION TWO

(a). A bottle containing 0.015kg of water at $0\ ^0C$ is placed in a thermally insulated box. The air in the box is at -15 ^0C. After equilibrium has been attained, all the water solidifies. The ice and air assume a temperature of $0\ ^0C$.

(a) What is the change in entropy of the water (3 marks)

(b) Estimate the change in entropy of the air. (3 marks)

(b). State any four types of thermometers and their temperature ranges. (4marks)

(c). (i). How much heat is required to raise the temperature of 0.6m^3 of Nitrogen at a pressure of 3 atm from 20^{0}C to 26^{0}C? (3 marks)

(ii). What is the pressure of the gas at 26^{0}C? (2 marks)

QUESTION THREE

(a). A Carnot engine is operated between two heat reservoirs at temperatures of 400K and 300K.

(i). If the engine receives 5.023kJ of heat from the reservoir at 400K in each cycle, how many calories does it reject to the reservoir at 300K? (3 marks)

(ii). If the engine is operated as a refrigerator (i.e. in reverse) and receives 1200cal from the reservoir at 300K, how many calories of heat does it deliver to the reservoir at 400K? (3 marks)

(b). With an aid of a diagram show the efficiency of an ideal refrigerator (5 marks)

(c). Derive Vander Waals equation of state (4 marks)

QUESTION FOUR

(a). Find the theoretical efficiency of a diesel engine which has a compression ratio of 15 and an expansion ratio of 5. (Let γ =1.4) (4 marks)

(b). A gas is heated and allowed to expand doing 1.01×10^5J of work. If 3×10^5J of heat enters during the expansion, what is the change in internal energy of the gas? (3 marks)

(c). Derive expressions for the change in entropy for the following processes

(i) Isothermal (2 marks)

(ii) Adiabatic (2 marks)

(iii) Isovolumetric (2 marks)

(iv) Isobaric (2 marks)

QUESTION FIVE

(a). A hot silver block of mass 0.20kg is placed in water in a copper container of mass 0.050kg. If the quantity of water was 0.2l at an initial temperature of 25^0C and the initial temperature of the silver block was 90^0C, find the equilibrium temperature reached by the block and the water. (6 marks)

(b). Distinguish between a reversible and irreversible process, illustrate your answer by use of some examples (4 marks)

(c). Calculate the net work done per cycle by a heat engine which is operating around the cycle shown in the figure below. ($P_{1,2}=1.0\times10^5$Pa, $P_{3,4}=2.5\times10^5$Pa, $V_{2,3}=4\times10^{-4}m^3$, $V_{4,1}=3\times10^{-3}m^3$) (5 marks)

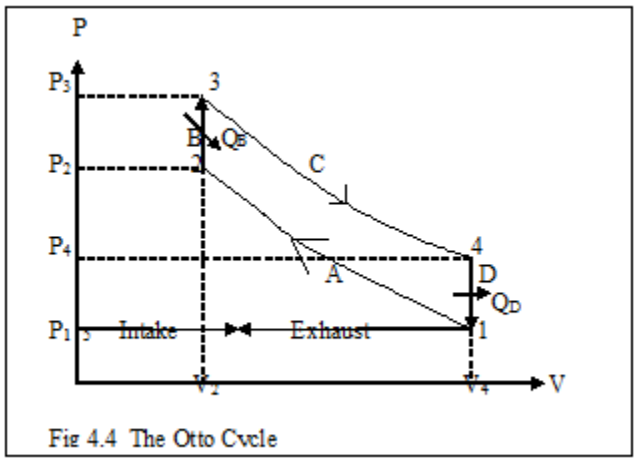

Fig 4.4 The Otto Cycle