UNIVERSITY OF EMBU

2017/2018 ACADEMIC YEAR

SECOND SEMESTER EXAMINATIONS

THIRD YEAR EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE AND BACHELOR OF EDUCATION SCIENCE

SPH 302: THERMODYNAMICS

DATE: APRIL 3, 2018 **TIME: 2:00-4:00PM**

INSTRUCTIONS:

Answer Question ONE and ANY Other TWO Questions.

Constants:

$c = 3.0\times10^{8}$ m/s $k = 1.38 \times 10^{-23} JK^{-1}$

$g = 10\ ms^{-2}$

$\varepsilon_o = 8.86 \times 10^{-12}\ C^2/Nm^2$

$\mu_o = 4\pi \times 10^{-7}$ N/A.M

Specific heat capacity of iron = 0.45 kJ/kgK

Specific heat capacity of water = 4.18 kJ/kgK

Specific heat capacity of lead = 145 J/kgK

QUESTION ONE (30 MARKS)

a) A gas was contained in a cylinder with a moveable piston on which a heavy block was placed. Consider that region outside the chamber was evacuated and total mass of the block and the moveable piston was 102 kg. When 2140 J of heat flows into the gas, the internal

energy of the gas increased by 1580J. Determine the distance through which the piston rises. (3 marks)

b) An internal combustion engine takes in a mixture of fuel and air at 27°C and the highest temperature after combustion was 427°C. Find the Carnot efficiency of an engine working between these two limits of temperature. (2 marks)

c) Briefly explain the concept of availability in thermodynamics with respect the second law of thermodynamics. (3 marks)

d) Explain the significance of the absolute zero temperature in nature. (3 marks)

e) Differentiate between critical point and triple point of a substance. (2 marks)

f) Explain the properties associated with a heat bath in thermodynamics (4 marks)

g) Using thermodynamic potentials explain the physical significance of Maxwell's relations. (4 marks)

h) Briefly explain the physical significance of cryogenics (3 marks)

i) Calculate the root mean square speed of a dust particle of mass 4×10^{-17} kg in air at 0^{o}C and 1 atmospheric pressure. (2 marks)

j) A steel drill rotating at 180 rpm was used to drill a hole in a block of steel. The mass of the steel block and the drill is 180 g. If the entire mechanical work was used up in producing heat and the rate of rise in temperature of the block and the drill was 0.5^{o}C. Find the rate at which the drill was working. (2 marks)

k) A mass of gas occupies 100 cm^3 at a temperature of 50^{o}C. Find the temperature at which its volume will double if its pressure is kept constant. 2 marks)

QUESTION TWO (20 MARKS)

a) Consider a cylinder fitted with a frictionless and free piston of area of cross sectional A. Suppose v_1 is the volume enclosed in the cylinder, show that the work done during expansion of 1 g of gas at constant pressure is given by:

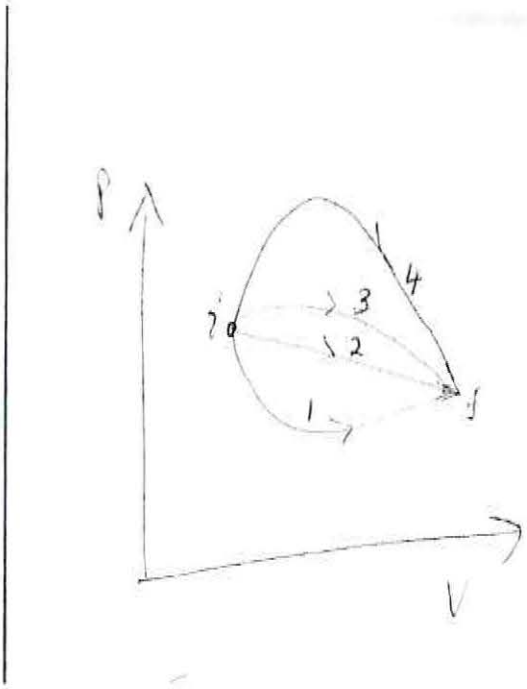
$$W = R(T_2 - T_1)\text{J}$$ (7 marks)

b) A block of iron weighing 100 kg and having a temperature of 100 °C was immersed in 50 kg of water at a temperature of 20 °C. Determine the change in entropy of the combined system

of iron and water.

(8 marks)

c) Figure 1 shows four paths on a PV diagram which a gas can be taken through from state an initial state i to a final state f.



Identify and explain the path that would result in greatest work as the system moves from an initial state i to the final state f. (5 marks)

QUESTION THREE (20 MARKS)

a) Suppose m grams of a gas having an initial volume and temperature v_1 and T_1 respectively was heated at constant pressure such that it achieved volume v_2 and temperature T_2 respectively. Show that the relationship between its specific heat at constant pressure and its specific heat at constant volume is given by:

$$c_p - c_v = \frac{R}{J}$$ (10 marks)

b) A thermometer of mass 0.055 kg and heat capacity of 46.1 J/K read 15.0 °C. It was then completely immersed in 0.300 kg of water and it came to the same temperature as the

water. If the thermometer read 44.4 °C, find the temperature of the water before insertion of thermometer. (Neglect other heat losses)

(5 marks)

c) A machine was set to be operated by a power cycle capable of delivering a net work output of 415 kJ for an energy input by heat transfer of 1000 k J. The system undergoing the cycle receives heat from a source of 500 k and rejects it to a sink of 300 k, Determine whether the engine shall work or not.

(5 marks)

QUESTION FOUR (20 MARKS)

a) Briefly explain phase equilibrium in the context of no violation of the second law of thermodynamics. (10 marks)

b) In an experiment 200 g of lead at 200 °C was mixed with 400 g of water at 20 ° C. Find the difference in entropy of the system at the end from its value before mixing.

(10 marks)

QUESTION FIVE (20 MARKS)

a) Consider a perfect gas at initial states of P_1, V_1, T_1 , and ϕ_1 and the final condition represented by P_2, V_2, T_2 , and ϕ_2. Show that the general expression for the change in entropy is given by:

i. $\phi_2 - \phi_1 = 2.3 \left(c_p \, log_{10} \left(\frac{T_2}{T_1} \right) - \frac{R}{J} \times log_{10} \left(\frac{P_2}{P_1} \right) \right)$ (15 marks)

b) Consider three systems A, B and C which are in a closed system which is left alone for a long time. By use of this system explain the concept of temperature. (5 marks)

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