KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS
2020/2021 ACADEMIC YEAR

FOURTH YEAR SECOND SEMESTER
SPECIAL/SUPPLEMENTARY EXAMINATIONS

FOR THE DEGREE OF BSC (PHYSICS) AND BED (SCIENCE)

COURSE CODE: SPH 415

COURSE TITLE: THERMODYNAMICS

DURATION: 2 HOURS

DATE: 19/1/2022 **TIME:** 11-1PM

INSTRUCTIONS TO CANDIDATES

- Answer **QUESTION ONE** (Compulsory) and any other two (2) Questions.
- Indicate **answered questions** on the front cover.

Start every question on a new page and make sure question's number is written on each page
This paper consists of **3** printed pages. Please Turn Over

Gas constant R=8.314 J/mol. K, specific heat capacities for water=4186 J/kg. K; specific heat capacity for steam=2010 J/Kg. K; specific heat capacity for glass=837 J/Kg. K; Latent heat of vaporization for steam=2.26x10 ^{6} J/Kg. ***Stefan–Boltzmann constant $\sigma=5.670 \times 10^{-8}$ W/m2 · K4.***

QUESTION ONE [30 Marks]

a. Define the following terms as used in thermodynamics: (3 marks)
   i. A system
   ii. Isothermal process
   iii. Adiabatic process

b. Describe the difference between an intensive and extensive property. Give two examples of each type.

(3 marks)

c. Consider a person standing in a room maintained at 22°C at all times. The inner surfaces of the walls, floors, and the ceiling of the house are observed to be at an average temperature of 10°C in winter and 25°C in summer. Determine the rate of radiation heat transfer between this person and the surrounding surfaces if the exposed surface area and the average outer surface temperature of the person are 1.4 m2 and 30°C, respectively (emissivity of a person ε=0.95).

(4 marks)

d. A cylinder contains 3.00 mol of helium gas at a temperature of 300K.(i) If the gas is heated at constant volume, how much energy must be transferred by heat to the gas for its temperature to increase to 500K? (ii)How much energy must be transferred by heat to gas at constant pressure to raise the temperature to 500K? (iii) what is the work done by the gas in this isobaric process? (For helium C_v=12.5 J/mol.K, C_p=20.8 J/mol.K).

(6 marks)

e. Two solid spheres A and B have the same emissivity. The radius of A is four times the radius of B and the temperature of A is twice the temperature of B. Work out the ratio of the rate of heat radiated from A to that from B. (3 marks)

f. State the first law of Thermodynamics. (1 mark)

g. An ideal gas at 17^0C has a pressure of 760mmHg, and is compressed (i) isothermally, and (ii) adiabatically until its volume is halved, in each case reversibly. Calculate in each case the final pressure and temperature of the gas, assuming C_p=2100J/Kg. K and C_v=1500J/Kg. K (4 marks)

h.
   i. What is a Carnot cycle? (1 mark)
   ii. Derive the efficiency of an engine using Carnot cycle. (3 marks)

i. Distinguish specific heat at constant volume (C_v) from specific heat at constant pressure (C_p). (2 marks)

QUESTION TWO [20 Marks]

a) what mass of steam initially 130 ^{0}C is needed to warm 200g of water in 100-g glass container from 20.0 ^{0}C to 50.0 ^{0}C? (Specific heat capacity for water=4186 J/Kg.^{0}C;

Specific heat capacity for steam=2010 J/Kg.^{0}C; Latent heat of vaporization for water=2.26×10^6 J/kg)

(6 marks)

b) Describe the following modes of heat transfer: (i) Conduction (ii) Convection. (4 marks)

c) For the Van der Waals equation $p = \frac{RT}{V-b} - \frac{a}{V^2}$, (i) determine an expression for the exact differential dp, (ii) hence show that the mixed second partial derivatives of the obtained in (i) are equal and, (iii) develop an expression for the partial derivative $\left(\frac{\partial V}{\partial T}\right)_P$. (10 marks)

QUESTION THREE [20 Marks]

a) A 0.050 Kg ingot metal is heated to 200.0 ^{0}C and then dropped into a beaker containing 0.400 Kg water initially at 20.0^{0}C. If the final equilibrium temperature of the mixed system is 22.4 ^{0}C, find the specific heat of the metal. (3 marks)

b) Give the Clausius definition of change in entropy. (2 marks)

c) A tank used for filling helium balloons has a volume of 0.300 m3 and contains 2.00 mol of helium gas at 20.0°C. Assuming that the helium behaves like an ideal gas, (i) what is the total translational kinetic energy of the molecules of the gas? (ii) What is the average kinetic energy per molecule? (5 marks)

d) N atoms of a perfect gas are contained in a cylinder with insulating walls, closed at one end by a piston. The initial volume is V1 and the initial temperature T1. Find the change in temperature, pressure and entropy that would occur if the volume were suddenly increased to V2 by withdrawing the piston.

(5 marks)

e) Calculate the change of entropy involved in heating a gram-atomic weight of silver at constant volume from 0 ^{0}C to 30 ^{0}C. The value of C_v over this temperature may be taken as a constant equal to 5.85 cal/deg.mole.

(3 marks)

f) A body of constant heat capacity C_p and a temperature T_i is put into with a reservoir at temperature T_f, equilibrium between the body and reservoir is established at constant pressure. Determine the total entropy change and prove that it is positive for either sign of $\left(T_{f-T_i}\right)/T_f$. You may regard $\frac{|T_f-T_i|}{T_f} < 1$.

(5 marks)

QUESTION FOUR [20 Marks]

a) Consider a gas tank of volume V containing N gas molecules with total energy E. Given equation of state E (S, V, N) show $T \equiv \left(\frac{\partial E}{\partial S}\right)_{V,N}$, $P \equiv -\left(\frac{\partial E}{\partial V}\right)_{S,V}$ and $\mu \equiv \left(\frac{\partial E}{\partial N}\right)_{S,V}$ where T is the definition of temperature, P is the definition of pressure and μ is the definition of chemical potential. (9 marks)

b) Classify the variables in (a) above as extensive and intensive (2 marks)

c) Consider an ideal gas whose entropy is given as $s = n/2\ [\sigma + 5R \ln U/n + 2R \ln V/n]$, where n= number of moles, R= universal gas constant, U= internal energy, V= volume and σ =constant. Calculate C_p and C_v, the specific heats at constant pressure and volume. (9 marks)

QUESTION FIVE [20 Marks]

a) State the First-law of thermodynamics (2 marks)

b) One mole of a monatomic perfect gas initially at temperature T_0 expands from volume V_0 to $2V_0$. (a) at constant temperature (b) at constant pressure, calculate the work of expansion and the heat absorbed by the gas in each case. (5 marks)

c) For a mole of ideal gas at t=0 ^{0}C, calculate the work W (in Joules) in an isothermal expansion from V_0 to $10V_0$ in volume. (3 marks)

d) An ideal gas at 17^0C has a pressure of 760mmHg, and is compressed (i) isothermally (ii) adiabatically until its volume is halved, in each case reversibly. Calculate in each case the final pressure and temperature of the gas; (Cp=2100 Jkg-1K-1 and Cv=1500 JKg-1K-1). (6 marks)

e) A 1.0-mol sample of an ideal gas is kept at 0.0^0C during an expansion from 3.0L to 10.0L. How much work is done by the gas during the expansion? (4marks)

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