



KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS
2020/2021 ACADEMIC YEAR

FOURTH YEAR SECOND SEMESTER
MAIN EXAMINATIONS

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

COURSE CODE: SPH 415

COURSE TITLE: THERMODYNAMICS

DURATION: 2 HOURS

DATE: 6/10/2021

TIME: 8:00-10:00AM

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

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Gas constant $R=8.314 \text{ J/mol. K}$, 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= $2.26 \times 10^6 \text{ J/Kg}$. Legendre transformation of y is $\phi(\xi) = y - \xi x$; $\phi(\xi) = y(x) - x(dy / dx)$

SPH 415: THERMODYNAMICS

QUESTION ONE [30 Marks]

- a. Describe the difference between an intensive and extensive property. Give one example of each type. (3 marks)
- b. Define isolated system, closed system and open system. (3 marks)
- c. A household refrigerator with a coefficient of performance (COP) of 1.2 removes heat from the refrigerated space at a rate of 60 KJ/min. Determine:
- The electric power consumed by the refrigerator, and (2 marks)
 - The rate of heat transfer to the kitchen air. (2 marks)
- d. A piston-cylinder device contains a liquid-vapour mixture of water at 300K. During the constant-pressure process, 750 KJ of heat is transferred to the water. As a result, part of the liquid in the cylinder vaporizes. Determine the entropy change of water during this process. (2 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°C 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 $C_p=2100\text{J/Kg. K}$ and $C_v=1500\text{J/Kg. K}$ (4 marks)
- h.
- What is a Carnot cycle? (1 mark)
 - Derive the efficiency of an engine using Carnot cycle. (3 marks)
- i. A perfect gas may be defined as one whose equation of state is $PV=NKT$ and whose internal energy is only the function of temperature. For a perfect gas show that;
- $C_p=C_v+k$, where C_p and C_v are heat capacities (per molecule) at constant pressure and volume respectively. (2 marks)
 - The quantity PV^γ is constant during an adiabatic expansion (Assume $\gamma=C_p/C_v$ is constant). (2 marks)
- j. A 1.0 mol sample of an ideal gas is kept at 0.0 °C during an expansion from 3.0L to 10.0L. How much work is done by the gas during the expansion? (2 marks)

QUESTION TWO [20 Marks]

- a) what mass of steam initially 130 °C is needed to warm water in 100-g glass container from 20.0 °C to 50.0 °C? (7 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 $(T_f - T_i)/T_f$. You may regard $\frac{|T_f - T_i|}{T_f} < 1$.

(5 marks)

QUESTION FOUR [20 Marks]

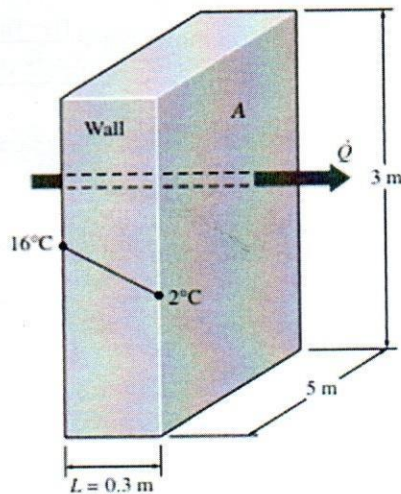
- a) Consider a gas tank of volume V containing N gas molecules with total energy E . Given equation of state $E(S, V, N)$ show $T \equiv \left(\frac{\partial E}{\partial S}\right)_{V,N}$, $P \equiv -\left(\frac{\partial E}{\partial V}\right)_{S,V}$ and $\mu \equiv \left(\frac{\partial E}{\partial N}\right)_{S,V}$ 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 marks) (2)
- 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]

(2 marks)

- a) State the First-law of thermodynamics
- 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 $t=0$ °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 170C 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; ($C_p=2100$ Jkg⁻¹K⁻¹ and $C_v=1500$ JKg⁻¹K⁻¹). (6 marks)
- e) Given $E=E(S, V; n_1, \dots, n_r)$, find a function whose natural variables are $T, V; n_1, \dots, n_r$. (4marks)

- b) Consider a 3-m-high, 5-m-wide, and 0.3-m-thick wall whose thermal conductivity is $k = 0.9 \text{ W/m} \cdot \text{K}$ shown below. On a certain day, the temperatures of the inner and the outer surfaces of the wall are measured to be 16°C and 2°C , respectively. Determine the rate of heat loss through the wall on that day. (3 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 solid that has a latent heat of fusion L_f melts at a temperature T_m . Calculate the change in entropy of this substance when a mass m of the substance melts. (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 m^3 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 V_1 and the initial temperature T_1 . Find the change in temperature, pressure and entropy that would occur if the volume were suddenly increased to V_2 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°C to 30°C . The value of C_v over this temperature may be taken as a constant equal to $5.85 \text{ cal/deg.mole}$. (3 marks)