MACHAKOS UNIVERSITY

University Examinations 2019/2020 academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR SPECIAL/SUPPLEMENTARY EXAMINATION FOR

BACHELOR OF SCIENCE IN MATHEMATICS,

BACHELOR OF SCIENCE TELECOMMUNICATION

BACHELOR OF EDUCATION (SCIENCE)

SPH 203: THERMAL PHYSICS 1

DATE: 21/1/2021 **TIME:2.00-4.00 PM**

INSTRUCTIONS:

1. Answer question No 1 and any other two questions.
2. Question No 1 carries 30 marks while the other two carry 20 marks each.
3. Use of sketches and brief illustrations where necessary
4. Read the instructions on the booklet keenly and adhere to them.

The following constants may be useful;

Universal gas constant R = 8.314 J/mol.K or 0.0821L.atm/mol.k

Wein constant for a black body b = 2.9×10^{-3} m.K

Stefans-Boltzman constant $\sigma = 5.67\times10^{-8}$ W/m^2.K^4

Avogadro constant = 6.023×10^{23}

Thermal conductivity of soda-lime glass = 0.96 W.m^{-1}k^{-1}

Boltzmann constant $k_B = 1.38 \times 10^{23}$J/K

Black body emissivity conctant $\varepsilon = 1$

Specific heat capacity of ice = 2000J/kgK

Specific heat capacity of water = 4200 J/kgK

Specific latent heat of fusion of ice= 335KJ/kgK

Specific latent heat of vaporization of water = 2260KJ/kgK

QUESTION ONE [30 MARKS]

a) Define the term system as used in thermodynamics (1 mark)

b) Briefly describe the following systems (3 marks)

i. Open system

ii. Closed system

iii. Isolated system

c) In a quasi-static isothermal expansion of a gas show that the work done is given by $W = -RT \ln \frac{V_2}{V_1}$ where V_2 is the final volume and V_1 (3 marks)

d) In an adiabatic process between two equilibrium states a certain system does work of 1055J on its surrounding. Calculate the corresponding change in internal energy of the system. (2 marks)

e) A sample of 3 moles of a gas was kept at 27^0c during an expansion from 5 litres to 18 litres. If the process was isothermal calculate

i. The work done by the gas in the process (3 marks)

ii. If the gas is returned to the original volume through an isobaric process, determine the work done by the gas (3 marks)

f) State the Zeroth law of thermodynamics (1 mark)

g) Define the term triple point (1 mark)

h) A window glass made of soda lime is 10mm thick and 1.2m by 1.2 m square separates a room at 21^oc from the outside at 40^oc. Calculate the amount of heat that enters the room through the window per day

(3 marks)

i) A 2000cm^3 aluminum container is filled with water at 0^oc and then heated to 90^oc. If the coefficient of linear expansion of aluminum is $24 \times 10^{-6 o}$c^{-1} and the coefficient of volume expansion of water is $6.3 \times 10^{-4\ o}$c^{-1}. Determine the volume of the spilled water (4 marks)

j) The molar mass of helium is 0.004 kg/mol. Determine the RMS speed of helium atoms at 10^oc (3 marks)

k) Sketch a pressure versus temperature diagram of pure water clearly showing its phases, triple point and critical point (3 marks)

QUESTION TWO [20 MARKS]

a) (i) Sketch a well labelled diagram of a system. Show its environment and defined boundaries and content (2 marks)

(ii) What type of a system is a vacuum flask? Explain your answer (2 marks)

b) The diagram in fig 1 shows systems A and B separated by adiabatic wall and a third one system C separated from the two by a diathermic wall.

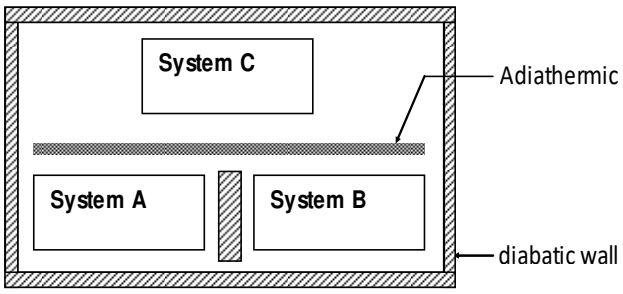

Fig 1.

Derive an equation for their equilibrium using the zeroth law (4 marks)

c) The equation of state for an ideal gas is PV = RΘ. Show that

$\beta = \Theta^{-1}$ and $k = P^{-1}$ (4 marks)

d) Explain the two approaches used to describe a thermodynamic system (4 marks)

e) Two moles of an ideal gas at 273K and pressure of $101325 Nm^{-2}$ expands from $0.056 m^3$ to $0.28 m^3$ at the same temperature. Determine the work done (4 marks)

QUESTION THREE (20 MARKS)

a) Derive an expression to show the relationship between the coefficient of linear expansion α and the coefficient of volume expansion β that $\beta = 3\alpha$ (3 marks)

b) An aluminum sphere of radius 3mm is at $100^o c$. Determine its new volume at $0.0^o c$ if the coefficient of linear expansion of the material is $2.4 \times 10^{-5}\ ^o c^{-1}$ (3 marks)

c) i State the Wein's displacement law (1 mark)

ii The sun's surface has a temperature of approcimately 5800K. If treated like a black body determine the peak intensity wavelength λ_{max} and the total radiation power per unit area (4 marks)

ii A man is at a temperature of 37^0c while his surrounding is at 21^oc. If the emissivity of his skin is 0.900 and his surface area is 2.2 m^2 calculate the net energy loss from his body in 2 minutes (3 marks)

d) A tank used to fill a balloon has a volume of $1m^3$ and contains 5 mol of a gas at 25^oc. If the gas behave like an ideal gas determine

i. Total translational kinetic energy of the gas molecules (3 marks)

ii. Average kinetic energy per molecule (3 marks)

QUESTION FOUR [20 MARKS]

a) An approximate equation of state of a real gas at moderate pressure, devised to take into account the finite size of molecules is $P(V-b)=R\Theta$ where b is a constant. Show that

$$\beta = \frac{1/\Theta}{1+Pb/R\Theta} \quad \text{and} \quad k = \frac{1/P}{1+Pb/R\Theta} \qquad \text{(6 marks)}$$

b) 100g of CO_2 occupies a volume of 55 litres at a pressure of 1atm. if the volume is increased to 80 litres at constant temperature, determine its new pressure (5 marks)

c) A mass of mercury at standard pressure and a temperature of 0^oC is kept at constant volume. If the temperature is raised to 10^oC find the final pressure
($\beta = 1.81 \times 10^{-4}\ K^{-1}$ and $k = 3.82 \times 10^{-11} Pa^{-1}$) (3 marks)

d) An ideal gas of volume V = 0.1 M^3 at a temperature of 273.15 and pressure of 10^5 Pa expands reversibly to 3 times its volume. Calculate the work done at

i. Constant volume (2 marks)

ii. Constant temperature (4 marks)

QUESTION FIVE [20 MARKS]

a) State the first law of thermal dynamics (1 mark)

b) Distinguish between adiabatic and isothermal processes (2 marks)

c) Show that the work done in an adiabatic expansion of an ideal gas is given by

$$W = \frac{P_1V_1 - P_2V_2}{\gamma - 1} \text{ where } \gamma = \frac{C_P}{C_V} \qquad \text{(4 marks)}$$

d) A typical room contains 2500 moles of air. Find the change in internal energy of this air when the room is cooled from 24°c to 12°c at constant pressure of 1 atmosphere. (Take air like an ideal gas and ($\gamma = 1.4$) (4 marks)

e) Find the amount of energy needed in the process of heating 20g of ice at -20°c to steam at 100°c (3 marks)

f) The diagram in figure 2 shows PV diagram of a system taken through a series of states.

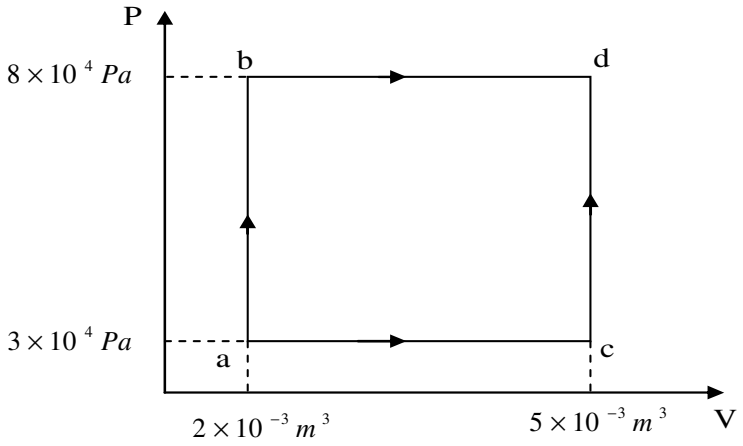

Figure 2

In process ab, 150J of heat are added to the system while in process bd 600J are added.

Find

i. The change in internal energy in process ab (1 mark)

ii. The change in internal energy in process abd (3 marks)

iii. Heat added in process acd (2 marks)