TECHNICAL UNIVERSITY OF MOMBASA

FACULTY OF APPLIED AND HEALTH SCIENCES
DEPARTMENT OF MATHEMATICS AND PHYSICS

UNIVERSITY EXAMINATIONS 2017/2018
APS 4204: THERMAL PHYSICS I

SERIES: SEPTEMBER 2018 TIME: 2 HOURS

Instructions to candidates:
You should have the following for this examination
Answer booklet, Examination paper, Examination Pass and Student ID.

1. This examination paper contains Five Questions:
   Question **ONE** carries **30 marks** while the rest of the questions carry **20 marks** each.
2. Answer question **ONE** and any **TWO** of the other questions.

All symbols have their usual meanings.

You may use the following constants:

i) Rydberg's Constant, $R = 8.31 JK^{-1}mol^{-1}$
ii) Wien's Constant, $B = 2.85 \times 10^{-3} mK$
iii) Stefans Constant, $\sigma = 5.67 \times 10^{-8} Wm^{-2}K^{-4}$
iv) $1\ cal = 4.1840\ Joule$

QUESTION ONE (30 Marks)

a) Define the following terms as used in thermodynamics
   i) Open system (1 mark)
   ii) Closed system (1 mark)
   iii) Isolated system (1 mark)

b) Distinguish between adiabatic and diathermic walls (2 marks)

c) State the properties of a good thermometric material (3 marks)

d) Show that the relation $pV^{\gamma} = const.$ holds in a quasi-adiabatic process of an ideal gas. (10 marks)

e) Briefly explain three equations of state connecting the macroscopic variables (p, V, T) (6 marks)

f) Derive the work W, in terms of specific heat capacity and temperature, which the gas does to its surrounding in a quasi-adiabatic process from (p_1, V_1, T_1) to (p_2, V_2, T_2). Assume the specific heat capacity to be constant. (6 marks)

QUESTION TWO (20 Marks)

a) State the possible thermodynamic interactions between a system and its environment (3 marks)

b) Distinguish between internal energy and enthalpy of a system (2 marks)

c) Given the density of air at normal temperature and pressure ($0^0 C$, 1 atm), $\rho = 0.00129 g/cm^3$, the specific heat at constant pressure, $c_p = 0.238\, cal/g \deg$, and its ratio to the isovolumic specific heat, $\gamma = c_p / c_v = 1.41$, calculate the mass, the Rydberg constant R, molar specific heat capacities c_p and c_v, and the relationship between calories and Joules.. Assume air to be an ideal gas with a volume of 22.41 at normal temperature and pressure.
(10 marks)

d) Differentiate between an ideal gas and a real gas (2 marks)

e) How much work is required to compress isothermally 2g of oxygen initially at STP to half its original volume? Assume its an ideal gas. (3 marks)

QUESTION THREE (20 Marks)

a) Distinguish between the following:
   i. Heat and temperature (2 marks)
   ii. Intensive and extensive thermodynamic quantities (2 marks)

b) Calculate the specific heat capacity at constant volume of air by assuming it to be a mixture of Oxygen O_2 and Nitrogen N_2 with a mass ratio of 23:77. The specific heat at constant volume of gaseous oxygen is 0.158 cal/gK and that of gaseous nitrogen is 0.176 cal/gK. (5 marks)

c) How much work is required to compress isothermally $2g$ of oxygen initially at normal temperature and pressure ($0^0 C$, 1 atm) to half its original volume? (Assume oxygen behaves as an ideal gas). The relative molecular mass of oxygen is 16.
(4 marks)

d) One gram (1g) of water $(1\ cm^3)$ becomes $1671\ cm^3$ of steam when boiled at constant pressure at $1.013 \times 10^5\ Pa$. The latent heat of vaporization at this pressure is $L_v = 2.256 \times 10^6$ J/kg. Find:
   i. Work done by water when it vaporizes (3 marks)
   ii. The latent of vaporization (2 marks)
   iii. Its increase in internal energy (2 marks)

QUESTION FOUR (20 Marks)

a) Define the following processes:
   i. Polytropic (1 mark)
   ii. Isothermal (1 mark)
   iii. Isentropic (1 mark)
   iv. Isochoric (1 mark)
   v. Adiabatic (1 mark)

b) A perfect gas with a γ value of 1.4 undergoes an expansion process from a pressure of 600 kPa. The ratio of specific volumes v_2 / v_1 is 3.0. Calculate the pressure P_2 at the end of the process if this is
   i. Polytropic with an index n of 1.6 (2 marks)
   ii. Isothermal (2 marks)
   iii. Isentropic (2 marks)

c) A perfectly insulated rigid tank with a volume of 0.2 m^3 contains a perfect gas which has a molar mass of 18 kg/mol and a ration of specific heats of 1.45. Initially the pressure and temperature in the tank are 9 bar and 320 K respectively. A fan inside the tank is spun at 3600rev/min for 20 seconds. The torque required to turn the fan is 30 Nm. Calculate the following:

i. The R, c_p , and c_v values of the gas and the mass of the gas in the tank in SI units (4 marks)

ii. The work input to the gas from the fan (2 marks)

iii. The final temperature of the gas. Explain briefly why the temperature continues to rise for a short time after the fan has stopped rotating. (3 marks)

QUESTION FIVE (20 Marks)

a) Explain the difference between the Planck's and the Rayleigh-Jeans spectral distribution law (4 marks)

b) The wavelength at the peak of a spectral distribution for a black body at 4300 K is 674 nm. At what temperature would the peak be at 420 nm? (3 marks)

c) A closed system containing argon undergoes a reversible isothermal process from an initial state (1) where P_1=50 bars, V_1=0.03 m^3, and T_1=450 K to state (2). The work done during the process is -100 kJ. The system is then heated reversibly at constant volume to final state (3). The total heat transferred during the two processes is 170 kJ. Treat argon as a perfect gas with c_p = 520 J/kgK and molar mass M = 40 kg/kmol. Calculate the following:

i. The mass of argon in the system (2 marks)

ii. The heat transferred during the constant volume processes (2)-(3) (4 marks)

iii. The final temperature, T_3. (5 marks)

iv. Sketch the processes on a pressure-volume diagram. (2 marks)