NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 1203 - THERMAL PHYSICS

BSc HONOURS PART I: *JUNE 2004* *DURATION: 3 HOURS*

ANSWER **ALL** PARTS OF SECTION A AND ANY **THREE** FROM SECTION B.
SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS

Boltzmann constant	σ	= 1.381×10^{-23} J/K
Universal gas constant	R	= 8.314 J/mol.K
Wien's constant	b	= 2.898 mmK
Heat of fusion for water	L	= 333 kJ/kg
Ice point		= 273.15K
Steam point		= 373.15K
Zinc point		= 692.664K

SECTION A

1. (a) Explain briefly, the meaning of the following terms:
   (i) Thermodynamic property [2]
   (ii) Thermodynamic equilibrium [2]
   (iii) Equation of state. [2]

   (b) A slab of copper of cross sectional area $20cm^2$ and length 3cm has its ends A and B kept at 100°C and 50°C respectively. How much heat flows from A to B every second?
   [conductivity of copper k = 397W/m.°C] [4]

   (c) (i) What do you understand by the term "ideal gas"? [3]
   (ii) Using the Kinetic Theory, show that the product of pressure (P) and volume (V) of a containerized gas speed is related to the root mean square speed $\overline{V^2}$ by the following equation:

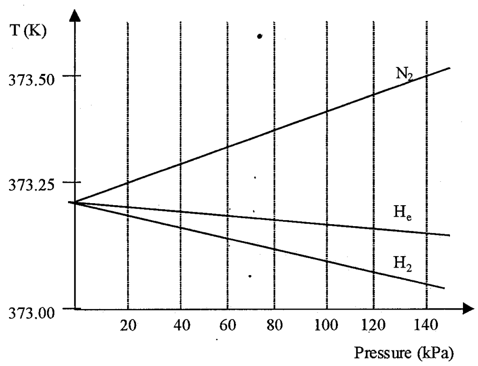
   $$PV = \frac{1}{3}Nm\overline{V^2}$$

   where N is the total number of molecules and m is mass of a molecule. [7]

(d) The first Law of Thermodynamics may be written as:
$du = dQ - dw$
What happens to these quantities for a process occurring:

(i) in adiabatic conditions [2]
(ii) in isochoric conditions [2]
(iii) for cyclical process [2]
(iv) for free expansion [2]

(e) The graph below shows that the measured temperature eventually becomes common for the same condition (Boiling point of water) for all the three gases as their amounts are continuously reduced in a constant volume gas thermometer.



(f) In light of the results shown in the graph, explain the concept of an "ideal gas temperature" and suggest why it is an important concept. [4]

(g) Differentiate between a microscopic and macroscopic variable. [4]

(h) Distinguish between a "reversible" and an "irreversible" process. [4]

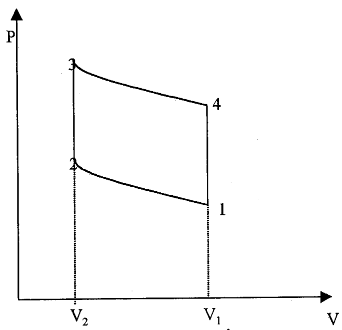
4. (a) Derive the Clausuis Clapeyron equation. [5]

(b) (i) How best would you define an engine? [3]

(ii) An inventor claims to have developed an engine that, during a certain time interval, takes in 110MJ of heat at 415K, rejects 50MJ of heat at 212k, and does 16.7kW.h of work.
Would you invest money in this project? Give a reason for your answer. [4]

(d) A lump of ice whose mass m is 235g melts (reversibly) to water, the temperature remaining at 0°C throughout the process.
(i) What is the entropy change for the ice? [4]
(ii) What is the entropy change for the environment? [4]
(iii) Give a reason for your answer in (ii) [2]

5. (a) An Otto cycle is the ideal air standard cycle for the petrol engine. The cycle is shown on the following PV diagram:



Show that the thermal efficiency of Otto cycle is given by

$\eta = 1 - \frac{1}{r^{(\gamma-1)}}$ where $\gamma = \frac{C_p}{C_v} \cong 1.4$ and $r = \left(\frac{V_1}{V_2}\right)$ [7]

(b) A family has two regrigerators in their living room. On a very hot afternoon, the father decides to cool the room by opening the refrigerator doors. Will he succeed in cooling the room? Explain your answer.

SECTION B

2. (a) What do you understand by the term 'Molar Heat Capacity'? [2]

(b) (i) Show that the molar heat capacity at constant volume $\left[C_v = \frac{1}{n}\frac{\Delta U}{\Delta T}\right]$ is given by $C_v = \frac{3}{2}R$. [2]

(ii) Show that the molar heat capacity at constant pressure C_p is given by $C_p = C_v - R$ [4]

(c) Prove that for an adiabatic expansion of an ideal gas:
PV^{γ} = constant
where γ is the ratio of molar heat capacities of the gas ie $\gamma = C_p/C_v$
[12]

3. (a) Describe the properties of a black-body radiator including, its nature, temperature dependence of wavelength for the most intense part of radiation. [5]

(b) If a body is at a temperature T_b in an environment of a slightly lower temperature T_a, show using Stefan -Boltzmann's law that the rate of loss of its heat to the environment $\left(\frac{dQ}{dt} = -k(T_b - T_a)\right)$ is estimated by Newton's law of cooling: ie $\frac{dQ}{dt} = 4\sigma T^3(\Delta T)$
where $T_b \approx T_a \approx T. / T = \frac{T_a + T_b}{2}$
[10]

(c) Determine the temperature of a black-body radiator whose peak intensity is at a wavelength of $1.07\,\mu m$. State the law used for this calculation.
[5]