NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 1203 - THERMAL PHYSICS

BSc HONOURS PART I: *MAY 2006* *DURATION: 3 HOURS*

ANSWER **ALL** PARTS OF SECTION A AND ANY **THREE** QUESTIONS 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) Briefly explain the meaning of the following terms:
   (i) temperature, [2]
   (ii) extensive variable, [2]
   (iii) steady state, [2]
   (iv) thermodynamic system. [2]

   (b) (i) Distinguish between a reversible and an irreversible process. [4]

   (ii) Make a list of any three factors that would render a process irreversible. [3]

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

   (d) (i) Define an equation of state. [2]

   (ii) Write down the Van der Waals equation of state explaining all the terms you have used. [3]

(iii) Derive the virial form of the above equation. [6]

(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.

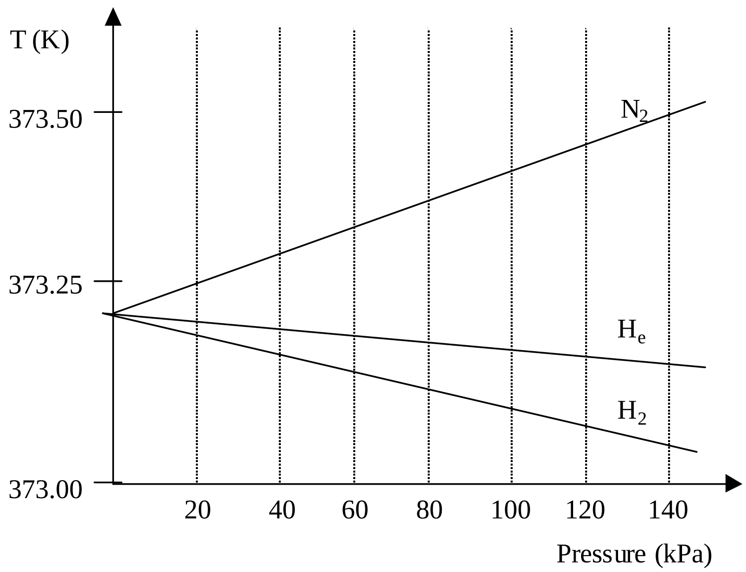

Figure 1.

(i) In the light of the results shown in the graph, explain the concept of an "ideal gas temperature" and suggest why it is an important concept. [6]

(ii) Differentiate between a microscopic and macroscopic variable. [2]

(iii) Write down the Kelvin statement of the Second Law of Thermodynamics. [2]

SECTION B

2. (a) Describe the properties of a black-body radiator including its nature and 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 $T_b \approx T_a \approx T$ *and* $T = \frac{T_a + T_b}{2}$

[10]

(c) Determine the temperature of a blackbody radiator whose peak intensity is at a wavelength of 1.07 μm. State the law used for this calculation.

[5]

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

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

(ii) Show that the molar heat capacity at constant pressure C_p for an ideal gas is given by $C_p = C_v + R$ [4]

(e) Prove that for a reversible adiabatic expansion of an ideal gas,
PV^{γ} = Constant
where γ is the ratio of molar heat capacities of the gas, i.e. $\gamma = C_p / C_v$ [12]

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]

(c) A lump of ice whose mass m is 235g melts (reversibly) to water, the temperature remaining at 0^oC throughout the process.

(i) What is the entropy change for the ice? [3]

(ii) What is the entropy change for the environment? [3]

(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:

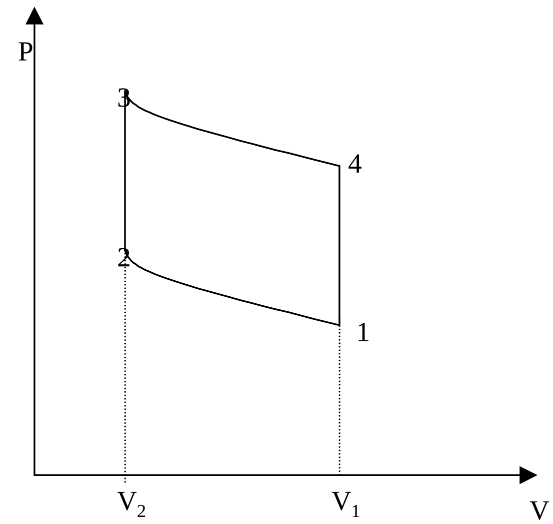

Figure 2.

Show that the thermal efficiency of the Otto cycle is given by

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

(b) A family has two refrigerators 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.

[5]

(c) A household refrigerator, whose coefficient of performance, k, is 4.7, extracts heat from the cooling chamber at the rate of 250J per cycle.

(i) How much work per cycle is required to operate the refrigerator?

[4]

(ii) How much heat per cycle is discharged to the room, which forms the high temperature reservoir of the refrigerator? [4]

6. (a) (i) Describe how enthalpic curves can be constructed using the results from

the Joule-Kelvin experiment [4]

(ii) Use the concept of the Inversion curve to explain how the Joule-Kelvin effect can be used in gas liquefaction. [6]

(b) Make use of an appropriate illustration and the corresponding derivation to show that the energy equation for steady flow is given by:

$$\left[h_1 + \frac{1}{2}v_1^2 + gz_1\right] - \left[h_2 + \frac{1}{2}v_2^2 + gz_2\right] - w + q = 0$$

where all symbols have their usual meanings. [10]

- END OF EXAMINATION -