NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 1203 – THERMAL PHYSICS

BSc HONOURS PART I: *MAY 2005* *DURATION: 3 HOURS*

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

SECTION A

1. (a) Define the following terms

(i) Thermodynamic system [1]
(ii) State variables [1]
(iii) Equation of state [1]
(iv) Diathermic wall [1]

(b) (i) A copper bar is heated to 300°C and the clamped rigidly between two fixed points. If the breaking stress of copper is 300 X 10^6Nm^{-2}, at what temperature will the bar break as it cools? [4]

(ii) Show that the heat lost per second through a cylindrical pipe to the atmosphere is given by:

$$\frac{dQ}{dt} = 2\pi k(T_1 - T_2)L / \ln(r_2 / r_1)$$ where

k – is thermal conductivity of pipe
r_1, r_2 are the inner and outer radius respectively
T_1, T_2 are the inside and outside temperatures of pipe
L is the length of the pipe. [4]

(iii) Use Stefan- Boltzmann law to show that Newton's law of cooling is given by:

$$\left[\frac{dQ}{dt} = -k(T_a - T_b)\right]$$, where all symbols have their usual meanings and $T_a \sim T_b$. [3]

(c) (i) State the Zeroth law of Thermodynamics [2]

(ii) Which fundamental concept of thermodynamics is brought about by this law? [1]

(iii) The equation of state for an ideal gas is given by PV =nRT. Show that the coefficient of volume expansivity of the gas is given by $1/T$ [3]

(d) (i) Write down Van der Wall's equation of state for a real gas and define all terms in the equation. [4]

(ii) Use the Binomial theorem to write the Van der Waal's equation of state in virial form. $\left(\text{ie} PV = A + \frac{B}{V} + \frac{C}{V^2} + -- \right)$ [4]

(e) (i) Write down the first law of Thermodynamics in differential form. [2]

(ii) Explain what happens to the quantities in the equation above in the following processes:

- in adiabatic conditions [2]
- in isometric conditions [2]
- for cyclical process [2]
- in free expansion [2]

2. (a) (i) Give one example each of a reversible and irreversible process. [2]
(ii) Explain for each of the above why it is reversible or irreversible. [2]

(b) Write briefly using diagrams and illustrations, on why the constant volume gas thermometer allows properties of gases to depend on temperature and not temperature to depend on properties of a particular gas. [7]

(c) A constant volume gas thermometer has a pressure of 1.5×10^4 Pa at the boiling point of water.

(i) Find the temperature of the boiling point of water [2]
(ii) Define the "triple point of water" [1]
[Pressure at triple point = $1.95x10^4 Pa$]

(d) In the Interval between 0°C and 700°C, a platinum resistance thermometer of definite specification is used for interpolating temperatures on the International Practical Temperature Scale. For the celcius temperature scale Tc, the variation of resistance with temperature is given by the formular: $R = R_o(1 + Atc + BTc^2)$ where R_o, A and B are constants determined by the measurements at the ice point, the steam point and the zinc point. If R = 10 000Ω at ice point 13964Ω at the steam point and 24172Ω at zinc point.

Find R_o, A and B. [6]

3. (a) (i) Show that the molar heat capacity at constant volume(Cv) for ideal gas is given by $Cv = \frac{3}{2}R$ [2]

(ii) Show that the molar heat capacity as constant pressure (Cp) is given by $Cp = Cv + R$ [2]

(b) 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 i.e $\gamma = {}^{Cp}/_{Cv}$ [10]

(c) (i) Write down the "engine" and the "refrigerator" statements of the Second low of Thermodynamics. [2]

(ii) A car engine with η = 22% operates at 95 cycles per second and does work at the rate of 89520 W. Find out the work, how much heat it absorbs, and how much heat it rejects per cycle. [4]

4. (a) Describe the Joule-kelvin or Porous Plug experiment [8]

(b) Show that for a Van der Waals gas:

$$Cp(T_2 - T_1) \approx \frac{2a - bRT_2}{V_2} - \frac{2a - bRT_1}{V_1}$$

where the symbols have their usual meanings. [8]

(c) Calculate the drop in temperature when Carbon dioxide expands from a specific volume of $4m^3$/mole.
Given that for carbondioxide:

$a = 366 \times 10^3 n\ m^4/(kgm - mole)^2$

$b = 0.025\ m^2/k\text{-}gm\text{-}mole$

$Cv = 3.38R$ [4]

5. (a) (i) Define the coefficient of linear thermal expansion giving a suitable equation and defining all the symbols. Show that the volume expansivity is approximately 3 times the linear expansivity [5]

(ii) A bar of total length L is made by joining end to end two bars of length L_1 and L_2 and expansivities $\propto_1$ and $\propto_2$ respectively. Show that the effective coefficient of linear expansion $\propto$ is given by: $\alpha = \frac{\alpha_1 L + \alpha_2 L_2}{L_1 + L_2}$ [5]

(iii) A composite bar of steel and brass of length 52,4 cm and effective linear thermal expansivity $13 \times 10^{-6}\ °C^{-1}$ is to be made. What are the length of the steel and brass bars?

$\propto$ steel = $11 \times 10^{-6}\ °C^{-1}$
$\propto$ brass = $19 \times 10^{-6}\ °C^{-1}$ [5]

(b) Show that the change in density $\Delta\ell$ with the change in temperature ΔT for a solid or gas is given by: $\Delta\ell$ where $\propto$ is the thermal volume expansivity [5]

6. (a) (i) Describe how enthalpic curves can be constructed using results from the Joule – Kelvin experiment [4]

(ii) By using the concept of the Inversion curve, explain how the Joule-Kelvin effect can be used in gas liquification.

(b) (i) Using an appropriate illustration and the corresponding derivation, show that the Energy Equation for steady flow is given by:

$$\left[h_1 + \frac{1}{2}V_1^2 gZ_1\right] - \left[h_2 + \frac{1}{2}V_2^2 + gZ_2\right] - w + q = o$$

Where all symbols have their usual meanings [10]

(ii) Write down the Kelvin statement of the Second Low of Thermodynamics. [2]

END OF EXAM