THERMAL AND KINETIC PHYSICS (PHY 214)

Coursework 2 : Week 2

ISSUE: Tuesday 05 October, 2010 HAND-IN: Tuesday 12 October, 2010

Course title, exercise number, student's name and exercise group (eg. KJD1) should appear on every sheet of the submitted coursework and sheets should be firmly held together (stapled).

Hand-in of worked exercises must take place by 4:00 p.m. on the above date at the labeled box provided outside the Teaching Administrators office on the first floor.

This time will be strictly adhered to and no late working will be accepted without written explanation to the course organiser. The solutions will appear shortly after this time on the TKP website.

Each coursework is worth 40 marks and the aggregate coursework mark will count 10% towards the final mark. An indicative mark scheme is given with each question.

Students should collect new exercise sheets in the Tuesday lecture or download them from the Web. Marked exercises will be returned in exercise classes or via the box outside the Teaching Administrators office on the first floor.

I will frequently use questions taken from Finn (Appendix 4 or (D)) for homework. Note that although the correct answers are given in the book, I want to see the method of solution. No credit will be given for simply writing down the answer.

QUESTION 1: **(12 marks)** An ideal gas is taken reversibly around a closed cycle a $\rightarrow$ b $\rightarrow$ c $\rightarrow$ d $\rightarrow$ a. Starting at pressure and volume P_a, V_a the process a $\rightarrow$ b is a constant pressure (isobaric) process from V_a to $V_b = 3V_a$, b $\rightarrow$ c is a constant volume(isochoric) process from P_b to $\frac{1}{4}P_b$, c $\rightarrow$ d is a constant temperature (isothermic) process ending at volume V_a and d $\rightarrow$ a is a constant volume (isochoric) process back to the begining.

i) Show the closed cycle by a sketch on a P - V diagram using arrows to indicate the direction of traverse of the cycle. **[6mks]**

ii) Show the same closed cycle but this time on a P - T diagram, again using arrows to indicate the sense of traverse of the cycle. **[6mks]**

QUESTION 2: (15 marks) For any system which can be described in terms of variables P, V, T we define the bulk modulus K and the thermal expansion coefficient β by

$$K = -V\left(\frac{\partial P}{\partial V}\right)_T \qquad\qquad \beta = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$$

(a) Derive in algebraic form for K and β for one mole of an ideal gas with equation of state $PV = RT$. Suppose we decrease the volume of this gas by 2% at constant temperature. By what percentage does the pressure change? NOTE: We have here small changes of volume ΔV and pressure ΔP . Which partial derivative relates these small changes? **[5mks]**

(b) For the ideal gas above, use the equation of state to obtain also the derivative $\left(\frac{\partial P}{\partial T}\right)_V$ and verify the cyclical identity

$$\left(\frac{\partial P}{\partial V}\right)_T\left(\frac{\partial V}{\partial T}\right)_P\left(\frac{\partial T}{\partial P}\right)_V = -1$$ **[5mks]**

(c) (From Finn 2.11) A certain block of metal may be considered as a P - V – T system. For such a system we define the thermal expansion coefficient β and the bulk modulus K as above. The experimentally measured values of β and K are

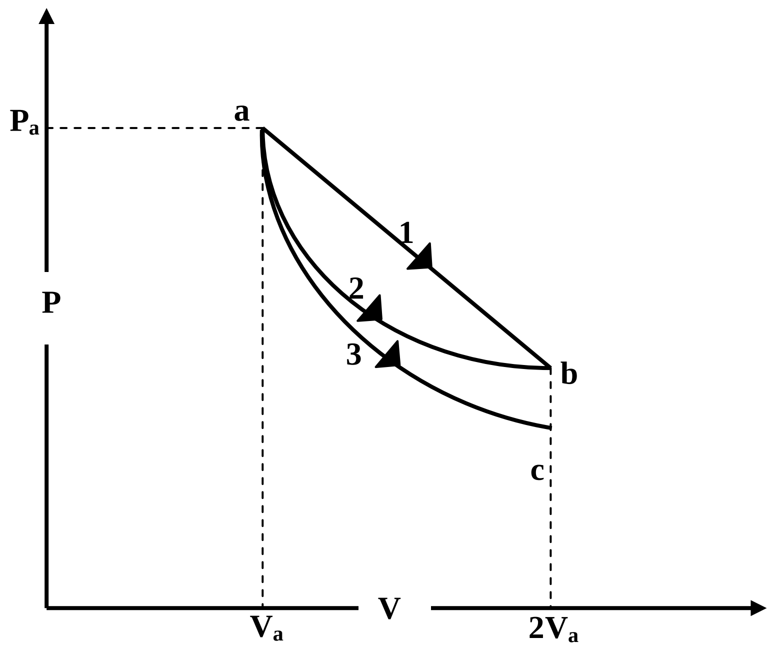
$$\beta = 5.0\times10^{-5} K^{-1} \qquad\qquad K = 1.5\times10^{11} Nm^{-2}$$

The block of metal is initially at a pressure of one atmosphere and at a temperatureof 20 ^{o}C. It is heated reversibly to 32 ^{o}C at constant volume. Use the cyclical identity on P - V - T to calculate the final pressure. **[5mks]**

HINT: Which partial derivative tells you the rate of change of pressure during this process?

QUESTION 3: (13 marks) One mole of a monatomic ideal gas is taken reversibly between various equilibrium states represented on the P - V indicator diagram below. The paths all start at pressure P_a and volume V_a and all end at volume $2V_a$. Path 1 is a straight line path as shown ending at pressure $\frac{P_a}{2}$ and path 2 is an isothermal path while on path 3 the pressure varies according to the equation

$$P = P_a \left(\frac{V_a}{V} \right)^{5/3}$$



i) For each of the three paths indicate on a T - V ***sketch how the temperature changes***. The sketch does not need to be numerically accurate, it need show only the ***qualitative change of temperature***, i.e., increasing, constant or decreasing. **[4mks]**

ii) For each path calculate the change in internal energy $\Delta U = U_{final} - U_{initial}$ and also the work done ON the gas. Express your answers in terms of the initial pressure and volume P_a and V_a. On which path does the magnitude of the internal energy change the most? **[9mks]**