

## THERMAL AND KINETIC PHYSICS (PHY 214)

### Coursework 3 :

### Week 3

**ISSUE: Tuesday 12 October, 2010 HAND-IN: Tuesday 19 October, 2010**

**Students name (top left corner), course title & exercise number and exercise group (top right corner)** should appear on every sheet of the submitted coursework and sheets should be firmly held together. A stapler is available if needed from the secretaries office.

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.

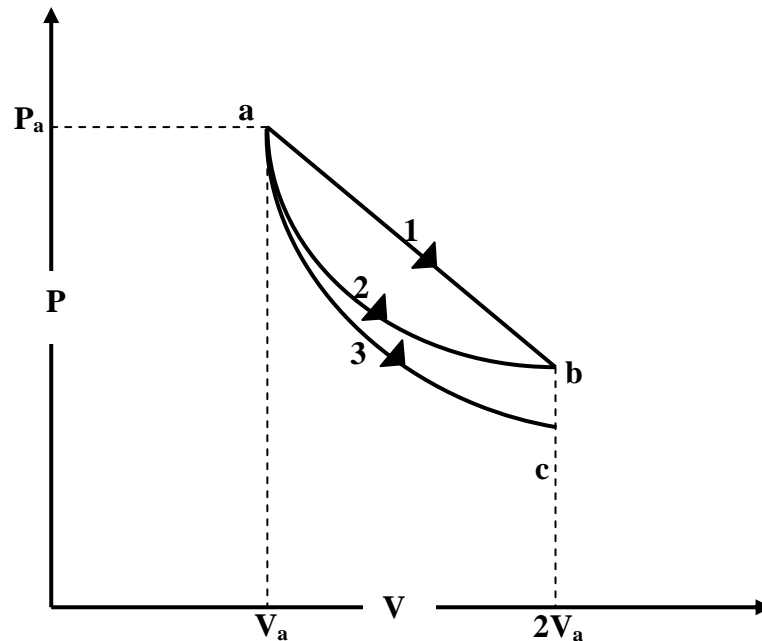
This time will be strictly adhered to and no late working will be accepted without written explanation to the course organiser. The solutions will appear shortly after this time on the TKP website.

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. **Note: *I want to see the method of solution. No credit will be given for simply writing down the answer.***

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.

**QUESTION 1: (10 marks)** We consider the same system as in Question 3 of the Week 2 exercises. One mole of a monatomic ideal gas is taken reversibly between various equilibrium states represented on the P - V indicator diagram overleaf. 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  $P_a/2$ , path 2 is an isothermal path while on path 3 the pressure varies according to the equation

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



Last week you calculated the work done ON the gas and the change in internal energy  $\Delta U = U_{final} - U_{initial}$  for each transformation shown above. This week use the First Law of Thermodynamics, to obtain expressions for the heat absorbed BY the gas in each transformation. Express all answers in terms of  $P_a$  and  $V_a$ , the pressure and volume in the initial state a. **[10mks]**

**NB. The answers from last week's coursework are now on the web.**

**QUESTION 2: (14 marks)** (Partly taken from Question 1 of the 2004 Exam paper)

a) During a reversible adiabatic expansion of an ideal gas, the pressure and volume at any moment are related by  $PV^\gamma = c$  where  $c$  and  $\gamma$  are constants. Show that the work done ON the gas in the process which takes it reversibly from a state  $(P_1, V_1)$  to a state  $(P_2, V_2)$  may be expressed as

$$W = \frac{P_2 V_2 - P_1 V_1}{\gamma - 1} \quad \text{[7mks]}$$

b) What is the adiabatic constant  $\gamma$  for monatomic Argon and diatomic Nitrogen respectively (you may take diatomic to refer to a rigid diatomic molecule with rotations but no internal vibrations)? A sample of one mole of each gas is confined in a cylinder with a movable piston at an initial pressure  $P_a$  and volume  $V_a$ . Each sample is then allowed to expand reversibly and adiabatically to a final volume  $3V_a$ .

Determine the work done BY each gas on its surroundings and express the answer in terms of  $P_a$ ,  $V_a$ . **[6mks]**

Which gas performs more work on its surroundings? **[1mk]**

**QUESTION 3: (16 marks)**

a) Adiabatic compression of a gas is an effective method of heating it. Write the adiabatic law,  $PV^\gamma = \text{const}$ , in terms of  $T$  and  $V$ . Use your result to calculate the derivative

$$\left. \frac{dT}{dV} \right|_{\text{Adiabatic}} \quad \text{[4mks]}$$

A rigid diatomic gas,  $\gamma = \frac{7}{5}$ , initially at a temperature of 300K, is suddenly compressed in volume by 10 percent. Treating the compression as adiabatic, estimate the change in temperature of the gas. **[4mks]**

b) A student pumps a bicycle tyre which then comes to thermal equilibrium with its surroundings at a temperature  $T_{\text{atm}}$  and with a pressure  $P_i$  which is greater than atmospheric pressure  $P_{\text{atm}}$ . The tyre valve is suddenly opened for a short time and air escapes until the tyre pressure is equal to atmospheric pressure at which point the valve is closed again. After some time the air remaining inside the tyre will again come to thermal equilibrium at  $T_{\text{atm}}$  but with a pressure  $P_f$ . Assume that the volume inside the tyre remains constant throughout and that the escape of air is rapid enough to regard the expansion of the escaping gas as an adiabatic expansion.

i) Show that immediately after the expansion the temperature  $T$  of the gas remaining inside the tyre is given by

$$\frac{T}{T_{\text{atm}}} = \left( \frac{P_i}{P_{\text{atm}}} \right)^{\frac{1}{\gamma} - 1}$$

Treating the air as a gas of rigid diatomic molecules, what would be the temperature ratio,  $\frac{T}{T_{\text{atm}}}$ , if  $P_i = 4P_{\text{atm}}$ ? **[4mks]**

ii) Show that we could obtain an experimental measurement of  $\gamma$ , the ratio of specific heats for the air, from

$$\frac{\ln\left(\frac{P_i}{P_{atm}}\right)}{\ln\left(\frac{P_i}{P_f}\right)} \quad [4\text{mks}]$$

**HINT:** *Take as the system of interest the air that is left in the tyre at the end of the process.*

**NOTE:** By using a glass container to define the volume more precisely this is a classic method of measuring specific heat ratios for a gas.