THERMAL AND KINETIC PHYSICS (PHY 214)

Coursework 4 : Week 4

ISSUE: Tuesday 19 October, 2010 HAND-IN: Tuesday 26 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.

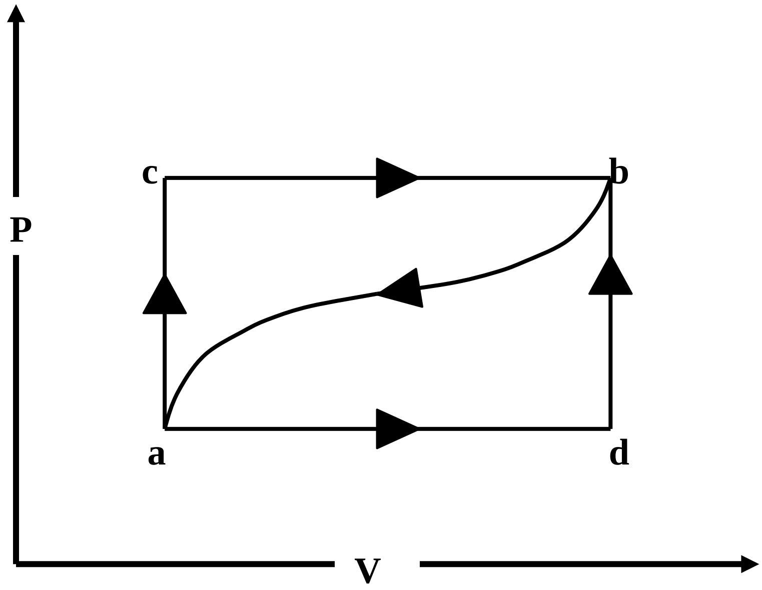
QUESTION 1: (8 marks) (From Question 1 of the 2005 examination – compare question 3.4 in Finn)

A system consists of gas contained in a cylinder fitted with a frictionless piston and is taken from state a to state b along the path a $\rightarrow$ c $\rightarrow$ b shown in the P - V diagram overleaf. During this process 200 J of heat flow into the system and the system does 100 J of work on its surroundings.

a) How much heat flows into the system along the path a $\rightarrow$ d $\rightarrow$ b if the work done by the gas system is 50 J? **[4mks]**

b) When the system is returned from b to a along the curved path, the system gives up 175 J of heat to the surroundings. What is the work done on the system? **[4mks]**

HINT: Read the words carefully to distinguish between WORK ON and WORK BY and HEAT ABSORBED and HEAT GIVEN UP. This question tests your understanding of the sign convention used in the First Law.



QUESTION 2: (12 marks)

a) Heat is supplied to an engine at the rate of 10^6 J per minute and the engine has an output of 10 horsepower. What is the efficiency of the engine and what is its heat output per minute? **[3mks]**

NOTE: 1 horsepower is 746 Watts

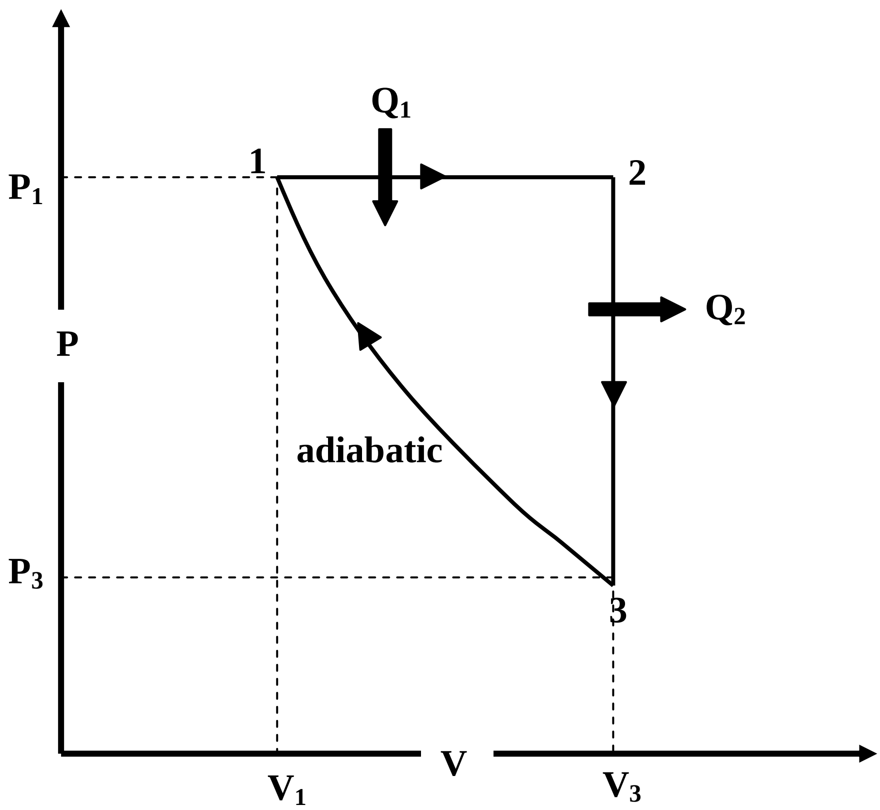
b) A heating salesman offers to sell you a heat pump which will maintain your house at a steady temperature of 25 ^oC by extracting heat from a disused well which is at a constant ground temperature of 5 ^oC. He promises that his product will deliver 20 kW hr of heat energy for every 1 kW hr of electrical energy consumed. Explain whether his claims for this device are realizable. **[3mks]**

c) 50 kg of water at 0 ^oC has to be frozen into ice in a refrigerator. The room temperature is 20 ^oC. What is the minimum work input to the refrigerator to achieve this? (Latent heat of fusion of water = 3.33×10^5 J kg^{-1}) **[6mks]**

NOTE: This question tests your understanding of what the figures of merit mean for engines, heat pumps and refrigerators.

QUESTION 3: (20 marks)

a) An engine is constructed using an ideal gas of rigid diatomic molecules, $U = \frac{5}{2}PV$, as its working substance and is operated reversibly around the cycle 1 $\rightarrow$ 2 $\rightarrow$ 3 $\rightarrow$ 1 shown in the figure below. The engine takes in heat Q_1 during the isobaric process 1 $\rightarrow$ 2, expels heat Q_2 during the isochoric process 2 $\rightarrow$ 3 and undergoes an adiabatic compression of the gas during 3 $\rightarrow$ 1.



i) Define the engine efficiency in words and express it in terms of the heat flows Q_1 and Q_2. **[2mks]**

ii) By applying the First Law to the processes 1 $\rightarrow$ 2 and 2 $\rightarrow$ 3, obtain expressions for the heat flows Q_1 and Q_2 in terms of the pressures P_1 and P_3 and the volumes V_1, V_3 corresponding respectively to the states 1, 3. **[3mks]**

iii) Show that the efficiency of the engine can be expressed in terms of the expansion ratio

$$r = \frac{V_3}{V_1}$$

as

$$\eta_E = 1 - \frac{5}{7}\frac{1 - r^{-7/5}}{1 - r^{-1}}$$ **[5mks]**

b) The engine is designed so that P_1 = 10 atm and P_3 = 1 atm while $V_3 = 10^{-3}$ m^3.

i) Calculate the compression ratio r, **[3mks]**

ii) Calculate the engine efficiency η_E. **[3mks]**

iii) Assuming that the value of V_3 has to remain fixed because of the size of the engine, explain how we should change the value of P_1 if we want to increase the work output for the same heat input. **[1mk]**

iv) Calculate the work produced by this engine in one cycle. **[3mks]**