**QA2** One mole of steam is contained within a vertical piston-cylinder arrangement, as shown in Figure A2.1. The system is perfectly sealed and friction can be considered negligible. The steam is initially at a temperature ($T$) of 200 ºC and at a pressure ($P$) of 2 bar. Under these conditions, the molar volume ($v$) of the steam is 0.01947 $m^3$/mol, and the behaviour of steam is well described by the virial equation of state, where $Z$ is the compressibility factor and $B$ is a constant with the value of -200 $cm^3$/mol:

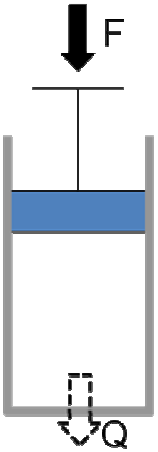

Figure A2.1

$$Z = 1 + \frac{B}{v}$$

A force of 5000 N is then made to act on the piston, pushing it very slowly downwards (so that the process can be considered reversible).

**a)** Consider first that the walls of the cylinder are in perfect thermal contact with the surroundings, so that the final temperature is the same as the initial temperature. If the final volume of the gas inside the cylinder is 0.0177 $m^3$/mol, calculate the work exerted on the gas by the piston.

[25 marks]

**b)** Calculate the radius of the cylinder. If you were unable to solve question A2a), assume a value of 500 J for the work done on the system.

[20 marks]

**c)** For any system undergoing an isothermal process, the change in internal energy is given by:

$$\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P$$

Making use of this expression, calculate the heat discarded by the system. Again, if you were unable to solve question A2a), assume a value of 500 J for the work done on the system. [25 marks]

**d)** Calculate the change in entropy of the steam during the process. Does this violate the Second Law of thermodynamics? Explain your answer. If you were unable to solve question A2c), assume a value of -400 J for the heat discarded. [15 marks]

**e)** Consider now that the cylinder is fitted with a heating jacket and that heat is slowly transferred to the system while the same force as before is acting on the piston, such that the pressure of the steam remains constant at 2 bar. If the heat transferred to the system is 750 J, what is the final temperature of the system? The molar heat capacities of steam are $c_V$ = 27.4 J/mol/K and $c_P$ = 36.3 J/mol/K, and can be assumed to be independent of temperature in this range [15 marks]