This is a 70 min. exam. NO WRITING IS PERMITTED IN THE FIRST 10 MIN.
For partial marking you need to SHOW ALL YOUR WORK.

1. Decide, with a justification, whether the following statements are true or false. [5 × 4 = 20]
   (a) The work done by a closed system can exceed the decrease in the system's internal energy.
   (b) For a closed system, the internal energy remains constant in an isothermal process.
   (c) Evaluation of the integral $\int_1^2 \frac{1}{V} dV$ requires a knowledge of the path.
   (d) For a closed system with only $P - V$ work, $\oint (PdV + VdP)$ vanishes.
   (e) For a closed system undergoing an adiabatic process between states I and II, the entropy change must be equal to or greater than zero.

2. Two identical bubbles of gas (A and B say) form at the bottom of a lake, then rise to the surface. Because the pressure is much lower at the surface than at the bottom, both bubbles expand as they rise. Bubble A rises quickly so that no heat is exchanged between it and the water. Bubble B however rises slowly so that it is always in equilibrium with the water which has the same temperature everywhere. Which of the two bubbles is larger when they reach the water surface? Explain your reasoning fully. [10]

3. Two tables summarizing the properties of water are given below. The first table has the properties of saturated water/steam while the second is for superheated steam. All values are for 1 kg and are measured relative to liquid water at the triple point (0.01 °C and 0.006 bar). Pressures are given in bars, where 1 bar = 10^5 Pa ≈ 1 atm, temperatures are in °C, enthalpy in kJ, and entropy kJ/K.

Table 1: Properties of saturated water/steam

T	P	H_{water}	H_{steam}	S_{water}	S_{steam}
0	0.006	0	2501	0	9.156
10	0.012	42	2520	0.151	8.901
20	0.023	84	2538	0.297	8.667
30	0.042	126	2556	0.437	8.453
50	0.123	209	2592	0.704	8.076
100	1.013	419	2676	1.307	7.355

Table 2: Properties of superheated steam

		Temperature				
P		200	300	400	500	600
1	H	2875	3074	3278	3488	3705
	S	7.834	8.216	8.544	8.834	9.098
3	H	2866	3069	3275	3486	3703
	S	7.312	7.702	8.033	8.325	8.589
10	H	2828	3051	3264	3479	3698
	S	6.694	7.7.123	7.465	7.762	8.029

   (a) In Table 1, why does the entropy of water increase with increasing temperature, while the entropy of steam decreases with increasing temperature? [10]
   (b) Imagine that the entropy part of Table 1 is missing; only the enthalpy data remains. Explain how you would recontruct the missing portion of the table. Use your method and explicitly show that at least two of the entries are consistent. [10]
   (c) How much data could you reconstruct if the entropy part were missing from Table 2? Explain. [10]
   (d) Decide whether the C_P of superheated steam at 1 bar is higher or lower than at 10 bar. [10]
   (e) Evaluate $\left(\frac{\partial S}{\partial P}\right)_T$ for superheated steam at 300K. [5]

4. Express $\left(\frac{\partial C_V}{\partial V}\right)_T$ in terms of the equation of state and/or their derivatives. [15]

5. For water at 25 °C, $\beta = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P = 2.57 \times 10^{-4}$ K^{-1} and $\kappa_T = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T = 4.52 \times 10^{-10}$ Pa^{-1}. Suppose you increase the temperature of some water from 20 °C to 30 °C. How much pressure must you apply to prevent it from expanding? Would you rather measure the heat capacity of liquid water at constant pressure or constant volume? Why? [10]