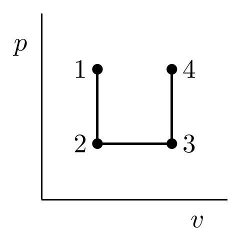
DO NOT WRITE ON THE BLUE TABLES.
RETURN THE BLUE TABLES WITH YOUR EXAM.
DO NOT STAPLE THE 3 EXAM SHEETS TOGETHER.

Put your answers on the same sheet as the question, Use many digits in your computation. You must give the units of your answers. You must write clearly. Encircle the right answer number in multiple choice. To correct, erase the wrong circle as well as you can and encircle the corrected answer number twice. Best possible answer for multiple choice. *Not following those requirements will result in reduced or no credit.*

1. (5%) Argon changes from 1.0 m^3/kg and 20°C to 1.0 m^3/kg and 30°C. Its specific enthalpy increases by 5.2 kJ/kg

2. (5%) To increase the temperature of normal air by 2°C/s at constant volume, we need to add 1.434 kJ/kg-s

3. (5%) An amount of substance undergoes a two-step process as shown in the figure.



The correct expression for the work performed by the substance in the process is, in terms of the intensive and extensive values of the states 1, 2, 3, and 4 (use subscripts) is: $p_2(V_3 - V_2)$

4. (5%) The specific heat at constant volume of propane at 227°C is 2.38165 kJ/kg-K

5. (5%) Argon at 100 kPa and 2 m^3/kg expands to 4 m^3/kg in a polytropic process with exponent 1.25. The specific work done by the argon on its surroundings is 127.28 kJ/kg

6. (5%) If the specific internal energy of a substance at normal atmospheric conditions is 200 kJ/kg and its specific volume is 3 m^3/kg, then its specific enthalpy is 500 kJ/kg

7. (5%) A frozen glass that can remove 5 kJ of heat can lower the temperature of 0.2 L of liquid water by 6 °C

8. (33%) A constant-pressure piston-cylinder setup contains 2kg of oxygen at 100 kPa within a volume of 2 m^3. The oxygen is heated until the volume doubles. What is the work done by the oxygen on the piston? What is the amount of heat added?

   You must show the derivations and reasoning completely and correctly for full credit. You must give units. Most accurate procedure only unless stated otherwise.

2a/18

$R = 0.2598$ kJ/kg K (from A5), p = constant

mass: $m_2 = m_1$

1st law: $m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$

O_2 2 kg, 100 kPa, 2 m^3 (I) → heat → $V_2 = 2V_1$, $V_2 = 4\ m^3$, $m_2 = 2$ kg, $v_2 = 2\ m^3/kg$

$v_1 = \frac{2\ m^3}{2\ kg} = 1\ m^3/kg$

${}_1W_2 = ?$, ${}_1Q_2 = ?$

${}_1W_2 = p(V_2 - V_1) = 100\ kPa\ (4-2)\ m^3 = 200\ kJ$

Answer: (beyond the immediate data above in red)

$p_1 v_1 = RT_1$ $\quad 100\ kPa\ 1\ m^3/kg = 0.2598\ \frac{kJ}{kg\,K}\ T_1$

$T_1 = 384.91\ K$

Table A8:

$u_1 = 228.37 + \frac{384.91 - 350}{400 - 350}(262.10 - 228.37) = 251.92\ \frac{kJ}{kg}$

$p_2 v_2 = RT_2$ $\quad 100\ kPa\ 2\ m^3/kg = 0.2598\ \frac{kJ}{kg\,K}\ T_2$

$T_2 = 769.822$

$u_2 = 519.02 + \frac{769.822 - 750}{800 - 750}(558.46 - 519.02) = 534.6563\ \frac{kJ}{kg}$

${}_1Q_2 = m(u_2 - u_1) + {}_1W_2 = 2\ kg\,(534.65 - 251.92)\ \frac{kJ}{kg} + 200\ kJ$

$= 765.47\ kJ$

(5) compute T_1, T_2 from $pV = mRT$
(4) mass conservation $m_1 = m_2$
(5) 1st law $m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$ solves ${}_1Q_2$ → $m c_p \Delta T = {}_1Q_2$ 2 pts
(5) ${}_1W_2$ from $p(V_2 - V_1)$
(4) $p_2 = p_1$
(5) u_1, u_2 from A8
(5) interpolate

$h_1 = 352.019$
$h_2 = 733.02$

9. (32%) Water enters a turbine with a velocity of 150 m/s at 200 kPa and 300°C at a rate of 2 kg/s. It exits the turbine at a pressure of 100 kPa and low velocity. The turbine produces 2 MW of power and loses 200 kW of heat to its surroundings. Construct and name the phase at the entrance in a *pv* diagram, narrow down the exit conditions, construct and name the phase at the exit using a *pv* diagram and find the exit temperature. Ignore the height difference between the entrance and exit.

   You must construct all phases that are not given in the *pv*-diagram, marking all lines used to do it with their values. Unambiguously number the phases in the diagram.

   You must show the derivations and reasoning completely and correctly for full credit. You must give units. Most accurate procedure only unless stated otherwise.