1. (30 pts) The speed of sound is given by the following relationship

\[ s_{\text{sound}} = \sqrt{-\left( \frac{\partial P}{\partial v} \right)_s \left( \frac{v^2}{MW} \right)} \]

where \( MW \) is the molecular weight. Let a gas obey the van der Waals equation of state given by

\[ P = \frac{RT}{v - b} - \frac{a}{v^2} \]

Find an expression for \( s_{\text{sound}} \) for this gas that contains only the following measurable variables and parameters: \( T, v, P, c_p, c_v, R, MW, a \) and \( b \) (containing no partial derivatives).

2. (35 pts) A gas that needs to be liquefied enters the isenthalpic expansion valve at a condition \( T_1 = 143 K, P_1 = 99 \text{ bars} \) and exits at a saturated condition \( T_2 = 78 K, P_2 = 0.957 \text{ bars} \). Using the departure functions, determine the fraction of the entering gas that is liquefied by the valve. Data for this gas are:

| \( \omega \) | 0.2 |
| \( T_c \) | 130 K |
| \( P_c \) | 33 bar |
| \( c_p^{\text{ideal}}/R \) | \( 2 + 0.0005 T(K) \) |
3. A Rankine cycle consists of steam entering a turbine with $\eta_{turbine} = 0.85$ at $T_1 = 600^\circ C$ and $P_1 = 12.5 \text{ MPa}$ and exits at $P_2 = 0.1 \text{ MPa}$. The compressor used was found to have efficiency $\eta_{compressor} = 0.70$.

a) (35 pts) Fill-in the missing values of the following table, where the process points refer to those given in Figure 1. Show how you obtained these values.

<table>
<thead>
<tr>
<th>Process Point</th>
<th>$T$ ($^\circ C$)</th>
<th>$P$ (MPa)</th>
<th>$\hat{h}$ (kJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>600</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>12.5</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 1. Rankine power cycle.](image)

b) (Bonus: 5 pts) Find the rate of steam flow $\dot{m}_{steam}$ (in kg/s) to generate a net power of 150 MW.