

Common Pitfalls in Solutions to Thermodynamics Problems

Adapted from

Thermodynamics: An Engineering Approach, 7th edition

by Yunus A. Çengel and Michael A. Boles

The following is a list of common pit falls frequently made during the solutions to thermodynamics problems.

1. **Units**—Equations must be dimensionally sound. The failure to use units in a consistent manor is one of the most frequent errors in the solution to thermodynamics problems. One must recognize that every term in an equation must have the same set of units. Often the knowledge of the units assigned to the parameters of a problem will lead to the definition of an equation that applies to the problem solution.
2. **System definition (closed vs. open)**—Systems must be well defined before a solution can proceed. Using energy balance equations developed for the open system or control volume cannot led to a successful completion of the solution to a closed system problem. Using energy balance equations developed for the closed system cannot led to a successful completion of the solution to an open system problem.
3. **Algebra**—Simple algebraic mistakes often occur in the solutions to thermodynamics problems. These mistakes unnecessarily lead to a great deal of student frustration that is not related to the thermodynamics theory applied to the problem solution.
4. **System sketches**—Students often omit sketches of the system hardware and/or omit indications of energy interactions at the system boundaries. These sketches are invaluable to the thought process required to understand the requirements of the problem solution. When sketching systems, show the directions of any mass transfer, heat transfer, or work crossing the system boundary.
5. **Specific heats**—Often there is confusion over the concepts associated with specific heats. The question asked is often “Do I use c_p or c_v in this solution?” The answer to this question depends on whether one needs to determine enthalpy changes or internal energy changes of the working fluid. If the working fluid of the problem is an ideal gas, c_p is used to calculated changes in enthalpy and c_v is used to calculate changes in internal energy. Because the enthalpy and internal energy of ideal gases are functions of temperature only, the methods for determining enthalpy changes, $\Delta h = \int c_p(T)dT$, and internal energy changes, $\Delta u = \int c_v(T)dT$, are true for an ideal gas in any process.
6. **Interpreting processes**—Often the importance of the role that the process plays in the solution technique applied to a thermodynamic problem is ignored. A process describes how the properties of a thermodynamic system are related as the process takes place. Most of the processes used in thermodynamics are ones in which one thermodynamic property is held constant. For instance, an isothermal (constant temperature) process can be accomplished by placing the system in an oil bath in which the oil temperature is controlled. As the process within the system takes place, the system’s temperature is maintained constant. This requires that other properties – pressure, volume, internal energy, enthalpy, etc. – all change together in a way to maintain constant temperature. As a consequence of the process there may be heat

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and work exchanged between the system and its surroundings. For a closed system, the boundary work can be determined as $w = \int P dv$, and the process relation is used to determine pressure as a function of volume so that the integral can be completed.

7. **Integrals of PdV**—Boundary work done by a working fluid within a system is given as the integral of PdV. Before one can successfully perform this integral, the process of the working fluid within the system must be known and the pressure as a function of volume must be determined. This integral is not, in general, equal to $P_2V_2 - P_1V_1$. This result is correct only when the process is constant pressure, and $P = P_1 = P_2$.
8. **Temperature**—When the value of temperature is substituted into an equation such as the ideal equation of state, the temperature must be in absolute units. A temperature change in the ordinary units, celsius or fahrenheit, is the same as the temperature change measured in kelvin or rankine units.
9. **Isothermal process versus adiabatic process**—An isothermal process is a process in which the temperature is maintained constant, and an adiabatic process is one in which there is no heat transfer. An isothermal process is not adiabatic. We often get confused with this concept because heat transfer is energy in transition due to a temperature difference. In this case the temperature difference for heat transfer occurs between the constant temperature system and its surroundings.
10. **Boundary work versus steady-flow work**—The boundary work per unit mass of system associated with the moving boundary of a closed system is determined by $w_b = \int P(v)dv$, while the steady-flow work per unit mass flowing through a control volume is $w_{sf} = -\int v(P)dP$. In each case the process provides the required pressure-volume relation required to complete these integrals. It should be noted that calculating the steady-flow work via the latter equation is often difficult because of the complicated nature of the integral. It is better first to try to determine steady-flow work by application of the first law for a steady-flow control volume and relate the work to the change in enthalpy. However, the steady-flow work of an incompressible fluid is quite easily determined from the integral since the specific volume of the incompressible liquid may be assumed to be constant.
11. **Entropy changes of ideal gases**—While internal energy and enthalpy are functions of only temperature for ideal gases, entropy of an ideal gas is a function of two independent intensive properties, often temperature and either pressure or volume. For constant specific heats, Δs for an ideal gas is $\Delta s = c_p \ln(T_2/T_1) - R \ln(P_2/P_1)$ or $\Delta s = c_v \ln(T_2/T_1) + R \ln(V_2/V_1)$. The entropy change of an ideal gas with variable specific heats is given by $\Delta s = s^\circ_2 - s^\circ_1 - R \ln(P_2/P_1)$. Property tables tabulate the standard state entropy s° as a function of temperature; however, the tables do not remind us to include the pressure term to complete the entropy change expression.