Objective: to understand and perform calculations using fundamental mechanical relations in thermodynamics

Problem 2. Smith, van Ness, Abbott, 1.5, page 16

Pressures up to 3,000 bar are measured with a dead-weight gauge. The piston diameter is 4 mm. What is the approximate mass in kg of the weights required?


The reading on a mercury manometer at 25 °C (open to the atmosphere at one end) is 56.38 cm. The local acceleration of gravity is 9.832 m·s⁻². Atmospheric pressure is 101.78 kPa. What is the absolute pressure in kPa being measured? The density of mercury at 25 °C is 13.534 g·cm⁻³.

Problem 4. Smith, van Ness, Abbott, 1.15, page 17

A gas is confined in a 1.25(ft)-diameter cylinder by a piston, on which rests a weight. The mass of the piston and weight together is 250(1bₘ). The local acceleration of gravity is 32.169(ft)(s)², and atmospheric pressure is 30.12(in Hg).

(a) What is the force in (lbᵣ) exerted on the gas by the atmosphere, the piston, and the weight, assuming no friction between the piston and cylinder?

(b) What is the pressure of the gas in (psia)?

(c) If the gas in the cylinder is heated, it expands, pushing the piston and weight upward. If the piston and weight are raised 1.7(ft), what is the work done by the gas in (ft·lbᵣ)? What is the change in potential energy of the piston and weight?

Problem 5. Smith, van Ness, Abbott, 1.18, page 18

An automobile having a mass of 1,250 kg is traveling at 40 m·s⁻¹. What is its kinetic energy in kJ? How much work must be done to bring it to a stop?

Chemical-plant equipment costs rarely vary in proportion to (i.e., linearly with) size. In the simplest case, cost $C$ varies with size $S$ according to the allometric equation

$$C = \alpha S^\beta.$$  

The size of the exponent $\beta$ is typically between 0 and 1. For a wide variety of equipment types, it is approximately 0.6.

(a) For $0 < \beta < 1$, show that cost per unit size decreases with increasing size. (“Economy of scale.”)

(b) Consider the case of a spherical storage tank. The size is commonly measured by internal volume $V'$. Show that $\beta = 2/3$. On what parameters or properties would you expect quantity $\alpha$ to depend?

Problem 7. Smith, van Ness, Abbott, 2.2, page 56

An insulated container filled with 25 kg of water at 20 °C is fitted with a stirrer, which is made to turn by gravity acting on a weight of mass 35 kg. The weight falls slowly through a distance of 5 m in driving the stirrer. Assume that all work done on the weight is transferred to the water and container, whose temperatures change together. Take the heat capacity of the container to be equivalent to 5 kg of water ($C_p = 4.18 \text{ kJ} \cdot \text{kg}^{-1} \cdot \text{oC}^{-1}$) and the local acceleration of gravity to be $9.8 \text{ m} \cdot \text{s}^{-2}$.

Determine:

(a) the amount of work done on the water-container system.

(b) the internal-energy change of the water-container system.

(c) the final temperature of the water-container system.

(d) the amount of heat that must be removed from the water-container system to return it to its initial temperature.

(e) the total energy change of the universe because of (1) the process of lowering the weight, (2) the process of cooling the water-container system back to its initial temperature, and (3) both processes together.