2.1 An insulated and nonconducting container filled with 10 kg of water at 20°C is fitted with a stirrer. The stirrer is made to turn by gravity acting on a weight of mass 25 kg. The weight falls slowly through a distance of 10 m in driving the stirrer. Assuming that all work done on the weight is transferred to the water and that the local acceleration of gravity is 9.8 m s\(^{-2}\), determine:

(a) The amount of work done on the water.
(b) The internal-energy change of the water.
(c) The final temperature of the water.
(d) The amount of heat that must be removed from the water 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 back to its initial temperature, and (3) both processes together.

2.4 Liquid water at 100°C and 1 bar has an internal energy (on an arbitrary scale) of 419.0 kJ kg\(^{-1}\) and specific volume of 1.044 cm\(^3\) g\(^{-1}\).

(a) What is its enthalpy?
(b) The water is brought to the vapor state at 200°C and 800 kPa, where its enthalpy is 2838.6 kJ kg\(^{-1}\) and its specific volume is 260.79 cm\(^3\) g\(^{-1}\). Calculate \(\Delta U\) and \(\Delta H\) for the process.

2.5 With respect to 1 kg of a substance,

(a) How much change in elevation must it undergo to change its potential energy by 1 kJ?
(b) Starting from rest, to what velocity must it accelerate so that its kinetic energy is 1 kJ?
(c) What conclusions are indicated by these results?

2.9 Nitrogen flows at steady state through a horizontal, insulated pipe with inside diameter of 2(in) [5.08 cm]. A pressure drop results from flow through a partially opened valve. Just upstream from the valve the pressure is 80(psia) [551.6 kPa], the temperature is 100(ºF) [37.8ºC], and the average velocity is 15(ft)(s) \([4.57 \text{ m s}^{-1}]\). If the pressure just downstream from the valve is 20(psia) [137.9 kPa], what is the temperature? Assume of nitrogen that \(PV/T = \text{const}\), \(C_v = (5/2)R\), and \(C_p = (7/2)R\).

3.1 An incompressible fluid is contained in an insulated cylinder fitted with a frictionless piston. Can energy as work be transferred to the fluid? What is the change in internal energy of the fluid when the pressure is increased from \(P_1\) to \(P_2\)?

3.5 An ideal gas, \(C_p = (5/2)R\) and \(C_v = (3/2)R\), is changed from \(P_1 = 1 \text{ bar}\) an \(V_1 = 10 \text{ m}^3\) to \(P_2 = 10 \text{ bar}\) and \(V_2 = 1 \text{ m}^3\) by the following mechanically reversible processes:

(a) Isothermal compression.
(b) Adiabatic compression followed by cooling at constant pressure.
(c) Adiabatic compression followed by cooling at constant volume.
(d) Heating at constant volume followed by cooling at constant pressure.
(e) Cooling at constant pressure followed by heating a constant volume.
Calculate \( Q \), \( W \), \( \Delta U \), and \( \Delta H \) for each of these processes, and sketch the paths of all processes on a single PV diagram.

**3.6** A rigid, nonconducting tank with a volume of 4 m\(^3\) is divided into two equal parts by a thin membrane. On one side of the membrane the tank contains nitrogen gas at 5 bar and 80°C, and the other side is perfect vacuum. The membrane ruptures and the gas fills the tank. What is the final temperature of the gas? How much work is done? Is the process reversible? Describe a reversible process by which the gas can be returned to its initial state. How much work is done (in the reversible process)? Assume nitrogen an ideal gas for which \( C_p = 7/2)R \) and \( C_v = (5/2)R \).

**3.8** One cubic meter of an ideal gas at 500 K and 2,000 kPa expands to ten times its initial volume as follows:
(a) By a mechanically reversible, isothermal process.
(b) By a mechanically reversible, adiabatic process.
(c) By an adiabatic, irreversible process in which expansion is against a restraining pressure of 100 kPa.
For each case calculate the final temperature, pressure, and the work done by the gas. \( C_p = 21 \text{ J mol}^{-1} \text{ K}^{-1} \).

**3.20** For methyl chloride at 125°C the virial coefficients are
\[
B = -207.5 \text{ cm}^3 \text{ mol}^{-1} \\
C = 18,200 \text{ cm}^6 \text{ mol}^{-2}
\]
Calculate the work of mechanically reversible, isothermal compression of 1 mol of methyl chloride from 1 bar to 60 bar at 125°C. Base calculations on the following forms of the virial equation:
(a) \[
Z = 1 + \frac{B}{V} + \frac{C}{V^2}
\]
(b) \[
Z = 1 + B'P + C'P^2
\]
Why don't both equations give exactly the same result?

**3.25** Calculate the molar volume of saturated liquid and the molar volume of saturated vapor by the Redlich/Kwong equation for the following and compare results with values found by suitable generalized correlations.
(a) Propane at 40°C where \( P_{sat} = 13.71 \text{ bar} \).
(q) Sulfur dioxide at 80°C where \( P_{sat} = 18.66 \text{ bar} \).