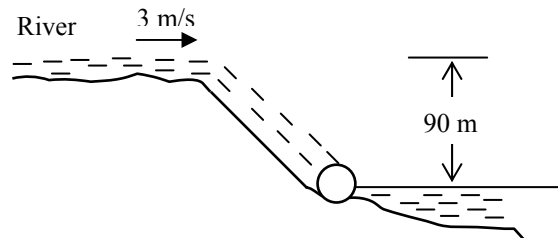


2-12 A river is flowing at a specified velocity, flow rate, and elevation. The total mechanical energy of the river water per unit mass, and the power generation potential of the entire river are to be determined.

Assumptions **1** The elevation given is the elevation of the free surface of the river. **2** The velocity given is the average velocity. **3** The mechanical energy of water at the turbine exit is negligible.

Properties We take the density of water to be $\rho = 1000 \text{ kg/m}^3$.

Analysis Noting that the sum of the flow energy and the potential energy is constant for a given fluid body, we can take the elevation of the entire river water to be the elevation of the free surface, and ignore the flow energy. Then the total mechanical energy of the river water per unit mass becomes



$$e_{\text{mech}} = pe + ke = gh + \frac{V^2}{2} = \left((9.81 \text{ m/s}^2)(90 \text{ m}) + \frac{(3 \text{ m/s})^2}{2} \right) \left(\frac{1 \text{ kJ/kg}}{1000 \text{ m}^2/\text{s}^2} \right) = \mathbf{0.887 \text{ kJ/kg}}$$

The power generation potential of the river water is obtained by multiplying the total mechanical energy by the mass flow rate,

$$\dot{m} = \rho \dot{V} = (1000 \text{ kg/m}^3)(500 \text{ m}^3/\text{s}) = 500,000 \text{ kg/s}$$

$$\dot{W}_{\text{max}} = \dot{E}_{\text{mech}} = \dot{m}e_{\text{mech}} = (500,000 \text{ kg/s})(0.887 \text{ kJ/kg}) = 444,000 \text{ kW} = \mathbf{444 \text{ MW}}$$

Therefore, 444 MW of power can be generated from this river as it discharges into the lake if its power potential can be recovered completely.

Discussion Note that the kinetic energy of water is negligible compared to the potential energy, and it can be ignored in the analysis. Also, the power output of an actual turbine will be less than 444 MW because of losses and inefficiencies.

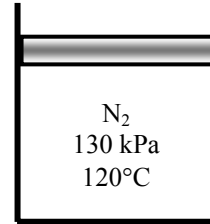
4-8 A piston-cylinder device contains nitrogen gas at a specified state. The boundary work is to be determined for the polytropic expansion of nitrogen.

Properties The gas constant for nitrogen is 0.2968 kJ/kg.K (Table A-2).

Analysis The mass and volume of nitrogen at the initial state are

$$m = \frac{P_1 V_1}{RT_1} = \frac{(130 \text{ kPa})(0.07 \text{ m}^3)}{(0.2968 \text{ kJ/kg.K})(120 + 273 \text{ K})} = 0.07802 \text{ kg}$$

$$V_2 = \frac{mRT_2}{P_2} = \frac{(0.07802 \text{ kg})(0.2968 \text{ kPa.m}^3/\text{kg.K})(100 + 273 \text{ K})}{100 \text{ kPa}} = 0.08637 \text{ m}^3$$



The polytropic index is determined from

$$P_1 V_1^n = P_2 V_2^n \longrightarrow (130 \text{ kPa})(0.07 \text{ m}^3)^n = (100 \text{ kPa})(0.08637 \text{ m}^3)^n \longrightarrow n = 1.249$$

The boundary work is determined from

$$W_b = \frac{P_2 V_2 - P_1 V_1}{1 - n} = \frac{(100 \text{ kPa})(0.08637 \text{ m}^3) - (130 \text{ kPa})(0.07 \text{ m}^3)}{1 - 1.249} = \mathbf{1.86 \text{ kJ}}$$

4-9 A piston-cylinder device with a set of stops contains steam at a specified state. Now, the steam is cooled. The compression work for two cases and the final temperature are to be determined.

Analysis (a) The specific volumes for the initial and final states are (Table A-6)

$$\left. \begin{array}{l} P_1 = 1 \text{ MPa} \\ T_1 = 400^\circ\text{C} \end{array} \right\} v_1 = 0.30661 \text{ m}^3/\text{kg} \quad \left. \begin{array}{l} P_2 = 1 \text{ MPa} \\ T_2 = 250^\circ\text{C} \end{array} \right\} v_2 = 0.23275 \text{ m}^3/\text{kg}$$

Noting that pressure is constant during the process, the boundary work is determined from

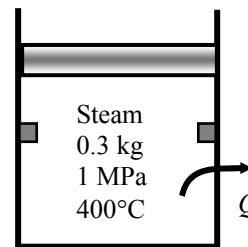
$$W_b = mP(v_1 - v_2) = (0.3 \text{ kg})(1000 \text{ kPa})(0.30661 - 0.23275) \text{ m}^3/\text{kg} = \mathbf{22.16 \text{ kJ}}$$

(b) The volume of the cylinder at the final state is 60% of initial volume. Then, the boundary work becomes

$$W_b = mP(v_1 - 0.60v_1) = (0.3 \text{ kg})(1000 \text{ kPa})(0.30661 - 0.60 \times 0.30661) \text{ m}^3/\text{kg} = \mathbf{36.79 \text{ kJ}}$$

The temperature at the final state is

$$\left. \begin{array}{l} P_2 = 0.5 \text{ MPa} \\ v_2 = (0.60 \times 0.30661) \text{ m}^3/\text{kg} \end{array} \right\} T_2 = \mathbf{151.8^\circ\text{C}} \quad (\text{Table A-5})$$



4-31 The table is to be completed using conservation of energy principle for a closed system.

Analysis The energy balance for a closed system can be expressed as

$$\underbrace{E_{in} - E_{out}}_{\substack{\text{Net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{system}}_{\substack{\text{Change in internal, kinetic,} \\ \text{potential, etc. energies}}}$$

$$Q_{in} - W_{out} = E_2 - E_1 = m(e_2 - e_1)$$

Application of this equation gives the following completed table:

Q_{in} (kJ)	W_{out} (kJ)	E_1 (kJ)	E_2 (kJ)	m (kg)	$e_2 - e_1$ (kJ/kg)
280	440	1020	860	3	-53.3
-350	130	550	70	5	-96
-40	260	300	0	2	-150
300	550	750	500	1	-250
-400	-200	500	300	2	-100

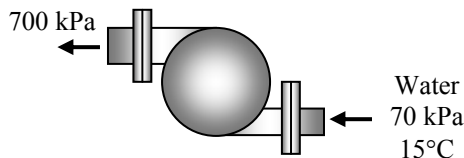
5-9 A water pump increases water pressure. The diameters of the inlet and exit openings are given. The velocity of the water at the inlet and outlet are to be determined.

Assumptions 1 Flow through the pump is steady. 2 The specific volume remains constant.

Properties The inlet state of water is compressed liquid. We approximate it as a saturated liquid at the given temperature. Then, at 15°C and 40°C, we have (Table A-4)

$$\left. \begin{matrix} T = 15^\circ\text{C} \\ x = 0 \end{matrix} \right\} \nu_1 = 0.001001 \text{ m}^3/\text{kg}$$

$$\left. \begin{matrix} T = 40^\circ\text{C} \\ x = 0 \end{matrix} \right\} \nu_1 = 0.001008 \text{ m}^3/\text{kg}$$



Analysis The velocity of the water at the inlet is

$$V_1 = \frac{\dot{m} \nu_1}{A_1} = \frac{4 \dot{m} \nu_1}{\pi D_1^2} = \frac{4(0.5 \text{ kg/s})(0.001001 \text{ m}^3/\text{kg})}{\pi(0.01 \text{ m})^2} = \mathbf{6.37 \text{ m/s}}$$

Since the mass flow rate and the specific volume remains constant, the velocity at the pump exit is

$$V_2 = V_1 \frac{A_1}{A_2} = V_1 \left(\frac{D_1}{D_2} \right)^2 = (6.37 \text{ m/s}) \left(\frac{0.01 \text{ m}}{0.015 \text{ m}} \right)^2 = \mathbf{2.83 \text{ m/s}}$$

Using the specific volume at 40°C, the water velocity at the inlet becomes

$$V_1 = \frac{\dot{m} \nu_1}{A_1} = \frac{4 \dot{m} \nu_1}{\pi D_1^2} = \frac{4(0.5 \text{ kg/s})(0.001008 \text{ m}^3/\text{kg})}{\pi(0.01 \text{ m})^2} = \mathbf{6.42 \text{ m/s}}$$

which is a 0.8% increase in velocity.