Homework-2 Solutions

Q. 1-109

Assumptions The weight of the cage and the ropes of the balloon is negligible.
Properties The density of air is given to be ρ_{air}= 1.16 kg/m^3. The density of helium gas is 1/7th of this.
Analysis The buoyancy force acting on the balloon is

$$\boldsymbol{V}_{balloon} = 4\pi r^3/3 = 4\pi(6\text{ m})^3/3 = 904.8\text{ m}^3$$

$$F_B = \rho_{\text{air}}\, g \boldsymbol{V}_{\text{balloon}}$$
$$= (1.16\text{ kg/m}^3)(9.81\text{m/s}^2)(904.8\text{ m}^3)\left(\frac{1\text{ N}}{1\text{ kg}\cdot\text{m/s}^2}\right) = 10{,}296\text{ N}$$

The total mass is

$$m_{\text{He}} = \rho_{\text{He}}\boldsymbol{V} = \left(\frac{1.16}{7}\text{kg/m}^3\right)(904.8\text{ m}^3) = 149.9\text{ kg}$$

$$m_{\text{total}} = m_{\text{He}} + m_{\text{people}} = 149.9 + 2\times 85 = 319.9\text{ kg}$$

The total weight is

$$W = m_{\text{total}}\, g = (319.9\text{ kg})(9.81\text{ m/s}^2)\left(\frac{1\text{ N}}{1\text{ kg}\cdot\text{m/s}^2}\right) = 3138\text{ N}$$

Thus the net force acting on the balloon is

$$F_{\text{net}} = F_B - W = 10{,}296 - 3138 = 7157\text{ N}$$

Then the acceleration becomes

$$a = \frac{F_{\text{net}}}{m_{\text{total}}} = \frac{7157\text{ N}}{319.9\text{ kg}}\left(\frac{1\text{kg}\cdot\text{m/s}^2}{1\text{ N}}\right) = \mathbf{22.4\ m/s^2}$$

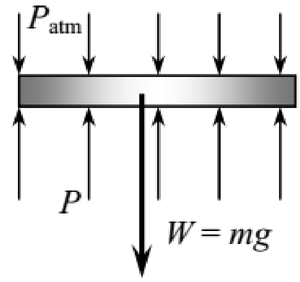
Q 1-114

Assumptions There is no blockage of the pressure release valve.
Analysis Atmospheric pressure is acting on all surfaces of the petcock, which balances itself out. Therefore, it can be disregarded in calculations if we use the gauge pressure as the cooker pressure. A force balance on the petcock ($\Sigma F_y = 0$) yields

$$W = P_{\text{gage}} A$$

$$m = \frac{P_{\text{gage}} A}{g} = \frac{(100 \text{ kPa})(4 \times 10^{-6} \text{ m}^2)}{9.81 \text{ m/s}^2} \left(\frac{1000 \text{ kg/m} \cdot \text{s}^2}{1 \text{ kPa}} \right)$$

$$= \mathbf{0.0408 \ kg}$$



Q 2-24C

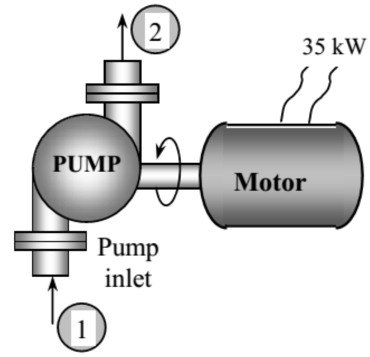
(*a*) From the perspective of the contents, heat must be removed in order to reduce and maintain the content's temperature. Heat is also being added to the contents from the room air since the room air is hotter than the contents. **(*b*)** Considering the system formed by the refrigerator box when the doors are closed, there are three interactions, electrical work and two heat transfers. There is a transfer of heat from the room air to the refrigerator through its walls. There is also a transfer of heat from the hot portions of the refrigerator (i.e., back of the compressor where condenser is placed) system to the room air. Finally, electrical work is being added to the refrigerator through the refrigeration system.
(*c*) Heat is transferred through the walls of the room from the warm room air to the cold winter air. Electrical work is being done on the room through the electrical wiring leading into the room.

Q 2-76
Assumptions: 1 The flow is steady and incompressible. **2** The elevation difference across the pump is negligible.
Properties: The density of oil is given to be $\rho = 860$ kg/m^3.
Analysis Then the total mechanical energy of a fluid is the sum of the potential, flow, and kinetic energies, and is expressed per unit mass as $e_{\text{mech}} = gh + Pv + V^2/2$.

To determine the mechanical efficiency of the pump, we need to know the increase in the mechanical energy of the fluid as it flows through the pump, which is

$$\Delta \dot{E}_{\text{mech,fluid}} = \dot{m}(e_{\text{mech,out}} - e_{\text{mech,in}}) = \dot{m}\left((Pv)_2 + \frac{V_2^2}{2} - (Pv)_1 - \frac{V_1^2}{2} \right) = \dot{\boldsymbol{V}}\left((P_2 - P_1) + \rho \frac{V_2^2 - V_1^2}{2} \right)$$

since $\dot{m} = \rho\dot{\boldsymbol{V}} = \dot{\boldsymbol{V}}/v$, and there is no change in the potential energy of the fluid. Also,



$$V_1 = \frac{\dot{\boldsymbol{V}}}{A_1} = \frac{\dot{\boldsymbol{V}}}{\pi D_1^2/4} = \frac{0.1\,\text{m}^3/\text{s}}{\pi(0.08\,\text{m})^2/4} = 19.9\text{ m/s}$$

$$V_2 = \frac{\dot{\boldsymbol{V}}}{A_2} = \frac{\dot{\boldsymbol{V}}}{\pi D_2^2/4} = \frac{0.1\,\text{m}^3/\text{s}}{\pi(0.12\,\text{m})^2/4} = 8.84\text{ m/s}$$

Substituting, the useful pumping power is determined to be

$$\begin{aligned}\dot{W}_{\text{pump,u}} &= \Delta \dot{E}_{\text{mech,fluid}} \\ &= (0.1\,\text{m}^3/\text{s})\left(400\text{ kN/m}^2 + (860\text{ kg/m}^3)\frac{(8.84\text{ m/s})^2 - (19.9\text{ m/s})^2}{2}\left(\frac{1\text{ kN}}{1000\text{ kg}\cdot\text{m/s}^2}\right)\right)\left(\frac{1\text{ kW}}{1\text{ kN}\cdot\text{m/s}}\right) \\ &= 26.3\text{ kW}\end{aligned}$$

Then the shaft power and the mechanical efficiency of the pump become

$$\dot{W}_{\text{pump,shaft}} = \eta_{\text{motor}}\dot{W}_{\text{electric}} = (0.90)(35\text{ kW}) = 31.5\text{ kW}$$

$$\eta_{\text{pump}} = \frac{\dot{W}_{\text{pump, u}}}{\dot{W}_{\text{pump, shaft}}} = \frac{26.3\text{ kW}}{31.5\text{ kW}} = 0.836 = \mathbf{83.6\%}$$

Discussion: The overall efficiency of this pump/motor unit is the product of the mechanical and motor efficiencies, which is 0.9×0.836 = 0.75.

Q 2-85

Assumptions: The city uses electricity produced by a natural gas power plant.

Properties: 0.59 kg of CO_2 is produced per kWh of electricity generated (given).

Analysis: Noting that there are 300,000 households in the city and each household consumes 700 kWh of electricity for refrigeration, the total amount of CO_2 produced is

$$\begin{aligned}\text{Amount of CO}_2\text{ produced} &= (\text{Amount of electricity consumed})(\text{Amount of CO}_2\text{ per kWh}) \\ &= (300{,}000\text{ household})(700\text{ kWh/year household})(0.59\text{ kg/kWh}) \\ &= 1.23\times10^8\ \text{CO}_2\text{ kg/year} \\ &= \mathbf{123{,}000\ \ CO_2\ ton/year}\end{aligned}$$

Therefore, the refrigerators in this city are responsible for the production of 123,000 tons of CO_2.