Homework #2 Solutions
Thermodynamics

1-56 The pressure in chamber 2 of the two-piston cylinder shown in the figure is to be determined.

*Analysis* Summing the forces acting on the piston in the vertical direction gives

$$F_2 + F_3 = F_1$$
$$P_2 A_2 + P_3 (A_1 - A_2) = P_1 A_1$$

which when solved for P_2 gives

$$P_2 = P_1 \frac{A_1}{A_2} - P_3 \left(\frac{A_1}{A_2} - 1 \right)$$

since the areas of the piston faces are given by
$A = \pi D^2 / 4$ the above equation becomes

$$P_2 = P_1 \left(\frac{D_1}{D_2} \right)^2 - P_3 \left[\left(\frac{D_1}{D_2} \right)^2 - 1 \right]$$

$$= (1000 \, \text{kPa}) \left(\frac{10}{4} \right)^2 - (500 \, \text{kPa}) \left[\left(\frac{10}{4} \right)^2 - 1 \right]$$

$$= \mathbf{3625 \, kPa}$$
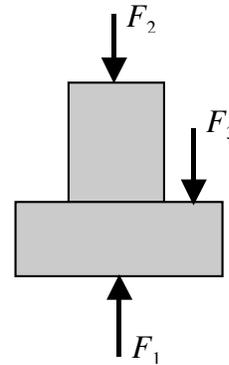
2-1C Initially, the rock possesses potential energy relative to the bottom of the sea. As the rock falls, this potential energy is converted into kinetic energy. Part of this kinetic energy is converted to thermal energy as a result of frictional heating due to air resistance, which is transferred to the air and the rock. Same thing happens in water. Assuming the impact velocity of the rock at the sea bottom is negligible, the entire potential energy of the rock is converted to thermal energy in water and air.

2-5C Thermal energy is the sensible and latent forms of internal energy, and it is referred to as heat in daily life.

2-6C The *mechanical energy* is the form of energy that can be converted to mechanical work completely and directly by a mechanical device such as a propeller. It differs from thermal energy in that thermal energy cannot be converted to work directly and completely. The forms of mechanical energy of a fluid stream are kinetic, potential, and flow energies.

2-14 Wind is blowing steadily at a certain velocity. The mechanical energy of air per unit mass and the power generation potential are to be determined.

Assumptions The wind is blowing steadily at a constant uniform velocity.
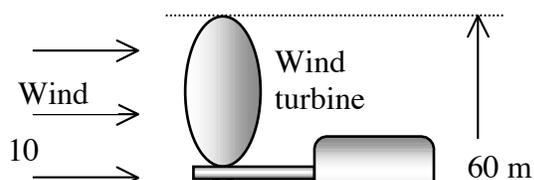
Properties The density of air is given to be $\rho = 1.25 \text{ kg/m}^3$.

Analysis Kinetic energy is the only form of mechanical energy the wind possesses, and it can be converted to work entirely. Therefore, the power potential of the wind is its kinetic energy, which is $V^2/2$ per unit mass, and $\dot{m}V^2/2$ for a given mass flow rate:

$$e_{mech} = ke = \frac{V^2}{2} = \frac{(10 \text{ m/s})^2}{2}\left(\frac{1 \text{ kJ/kg}}{1000 \text{ m}^2/\text{s}^2}\right) = 0.050 \text{ kJ/kg}$$

$$\dot{m} = \rho V A = \rho V \frac{\pi D^2}{4} = (1.25 \text{ kg/m}^3)(10 \text{ m/s})\frac{\pi(60 \text{ m})^2}{4} = 35{,}340 \text{ kg/s}$$

$$\dot{W}_{max} = \dot{E}_{mech} = \dot{m}e_{mech} = (35{,}340 \text{ kg/s})(0.050 \text{ kJ/kg}) = \textbf{1770 kW}$$

Therefore, 1770 kW of actual power can be generated by this wind turbine at the stated conditions.

Discussion The power generation of a wind turbine is proportional to the cube of the wind velocity, and thus the power generation will change strongly with the wind conditions.

2-31 A car is accelerated from rest to 100 km/h. The work needed to achieve this is to be determined.

Analysis The work needed to accelerate a body the change in kinetic energy of the body,

$$W_a = \frac{1}{2}m(V_2^2 - V_1^2) = \frac{1}{2}(800 \text{ kg})\left(\left(\frac{100{,}000 \text{ m}}{3600 \text{ s}}\right)^2 - 0\right)\left(\frac{1 \text{ kJ}}{1000 \text{ kg}\cdot\text{m}^2/\text{s}^2}\right) = \textbf{309 kJ}$$

2-47 The specific energy change of a system which is raised is to be determined.

Analysis Since the only property that changes for this system is the elevation, only the potential energy will change. The change in the specific energy is then

$$\Delta pe = g(z_2 - z_1) = (9.8 \text{ m/s}^2)(100 - 0) \text{ m}\left(\frac{1 \text{ kJ/kg}}{1000 \text{ m}^2/\text{s}^2}\right) = \textbf{0.98 kJ/kg}$$