Homework #3 Solutions
ME/CH EN 2300

#1 2-22C Point functions depend on the state only whereas the path functions depend on the path followed during a process. Properties of substances are point functions, heat and work are path functions.

#2 2-24C (*a*) The car's radiator transfers heat from the hot engine cooling fluid to the cooler air. No work interaction occurs in the radiator.

(*b*) The hot engine transfers heat to cooling fluid and ambient air while delivering work to the transmission.

(*c*) The warm tires transfer heat to the cooler air and to some degree to the cooler road while no work is produced. No work is produced since there is no motion of the forces acting at the interface between the tire and road.

(*d*) There is minor amount of heat transfer between the tires and road. Presuming that the tires are hotter than the road, the heat transfer is from the tires to the road. There is no work exchange associated with the road since it cannot move.

(*e*) Heat is being added to the atmospheric air by the hotter components of the car. Work is being done on the air as it passes over and through the car.

#3 4-1C It represents the boundary work for quasi-equilibrium processes.

#4 4-17 A gas in a cylinder expands polytropically to a specified volume. The boundary work done during this process is to be determined.

Assumptions The process is quasi-equilibrium.

Analysis The boundary work for this polytropic process can be determined directly from

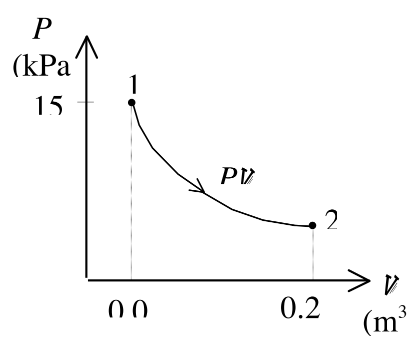
$$P_2 = P_1\left(\frac{V_1}{V_2}\right)^n = (150\ \text{kPa})\left(\frac{0.03\ \text{m}^3}{0.2\ \text{m}^3}\right)^{1.3} = 12.74\ \text{kPa}$$

and,

$$W_{b,\text{out}} = \int_1^2 P\,dV = \frac{P_2V_2 - P_1V_1}{1-n}$$

$$= \frac{(12.74\times 0.2 - 150\times 0.03)\ \text{kPa}\cdot\text{m}^3}{1-1.3}\left(\frac{1\ \text{kJ}}{1\ \text{kPa}\cdot\text{m}^3}\right)$$

$$= \mathbf{6.51\ kJ}$$



Discussion ***The positive sign indicates that work is done by the system (work output).***

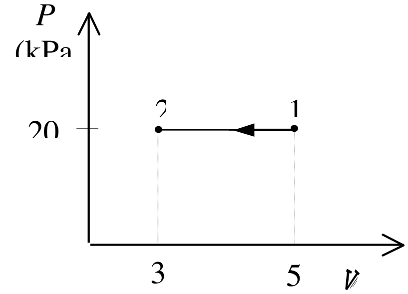
#5 4-5 Helium is compressed in a piston-cylinder device. The initial and final temperatures of helium and the work required to compress it are to be determined.

Assumptions The process is quasi-equilibrium.

Properties The gas constant of helium is R = 2.0769 kJ/kg·K (Table A-1).

Analysis The initial specific volume is

$$v_1 = \frac{V_1}{m} = \frac{5\ \text{m}^3}{1\ \text{kg}} = 5\ \text{m}^3/\text{kg}$$



Using the ideal gas equation,

$$T_1 = \frac{P_1 v_1}{R} = \frac{(200\ \text{kPa})(5\ \text{m}^3/\text{kg})}{2.0769\ \text{kJ/kg}\cdot\text{K}} = \mathbf{481.5\ K}$$

Since the pressure stays constant,

$$T_2 = \frac{V_2}{V_1} T_1 = \frac{3\ \text{m}^3}{5\ \text{m}^3}(481.5\ \text{K}) = \mathbf{288.9\ K}$$

and the work integral expression gives

$$W_{b,\text{out}} = \int_1^2 P\,dV = P(V_2 - V_1) = (200\ \text{kPa})(3-5)\ \text{m}^3\left(\frac{1\ \text{kJ}}{1\ \text{kPa}\cdot\text{m}^3}\right) = -400\ \text{kJ}$$

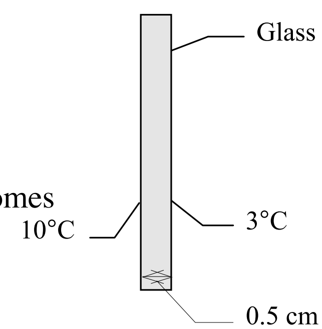
That is, $W_{b,\text{in}} = \mathbf{400\ kJ}$

#6 2-99 The inner and outer surfaces of a window glass are maintained at specified temperatures. The amount of heat transferred through the glass in 5 h is to be determined.

Assumptions **1** Steady operating conditions exist since the surface temperatures of the glass remain constant at the specified values. **2** Thermal properties of the glass are constant.

Properties The thermal conductivity of the glass is given to be $k = 0.78$ W/m·°C.

Analysis Under steady conditions, the rate of heat transfer through the glass by conduction is



$$\dot{Q}_{\text{cond}} = kA\frac{\Delta T}{L} = (0.78\ \text{W/m}\cdot{}^\circ\text{C})(2\times 2\ \text{m}^2)\frac{(10-3)^\circ\text{C}}{0.005\ \text{m}} = 4368\ \text{W}$$

Then the amount of heat transferred over a period of 5 h becomes

$$Q = \dot{Q}_{\text{cond}}\Delta t = (4.368\ \text{kJ/s})(5\times 3600\text{s}) = \mathbf{78{,}600\ kJ}$$

If the thickness of the glass is doubled to 1 cm, then the amount of heat transferred will go down by half to **39,300 kJ**.