Middle East Technical University
Department of Chemical Engineering
ChE204 Thermodynamics I (Section 2)
2013 - 2014 Spring Semester
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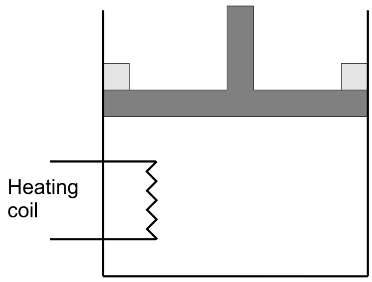
PROBLEM SET 2

Problems 1, 3 and 5 are homework due March 14

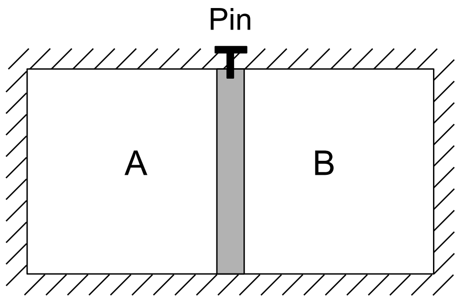
1) The frictionless piston-and-cylinder system shown here is subjected to 1.013 bar external pressure. The piston mass is 200 kg, it has an area of 0.15 m^2, and the initial volume of the entrapped ideal gas is 0.12 m^3. The piston and cylinder do not conduct heat, but heat can be added to the gas by a heating coil. The gas has a constant-volume heat capacity of 30.1 J/mol.K and an initial temperature of 298 K, and 10.5 kJ of energy is to be supplied to the gas through the heating coil.



a. If stops placed at the initial equilibrium position of the piston prevent it from rising, what will be the final temperature and pressure of the gas?

b. If the piston is allowed to move freely, what will be the final temperature and volume of the gas?

2) A rigid, well-insulated cylinder with a total volume of 2 L is divided into two equal parts as shown in the figure. Chamber A contains helium at 3 bar and 293 K. Chamber B contains nitrogen at 1 bar and 293 K. The cross sectional area of the piston is 0.01 m^2. The piston is a good conductor of heat with negligible mass and it is initially held in place by a pin.



The pin is then removed. The piston is not well lubricated and it moves with considerable friction. However, at equilibrium the pressures in both chambers are practically identical.

What are the pressures and temperatures of both chambers at equilibrium?

3) a. One mole of air undergoes the following reversible changes in a series of non-flow processes:

(i) From an initial state of 20°C and 1 bar, it is compressed adiabatically to 5 bar.

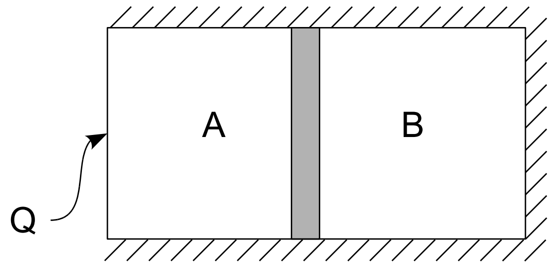
(ii) It is then cooled to 20°C at a constant pressure of 5 bar.

(iii) Finally the gas is expanded isothermally to its original state.

Calculate Q, W, ΔU and ΔH for each of the three processes and for the entire cycle.

b. Repeat the calculations for the same changes of state accomplished irreversibly, the efficiency of each process being 75% compared with reversible operation.

4) A rigid, horizontal cylinder, closed at both ends and insulated on all but the left end, contains a frictionless nonconducting piston. On each side of the piston is 10 L of an inert, monatomic ideal gas at 1 bar and 20°C. Heat is slowly supplied to the gas on side A until the piston has compressed the gas on side B to 1.5 bar.



a. How much work is done on the gas on side B?

b. What is the final temperature of the gas on side B?

c. What is the final temperature of the gas on side A?

d. How much heat is added to the gas on side A?

5) Captain Schultz, the star high diver of the circus, insists that his bath always be at exactly 37°C, body temperature, and measures the temperature of the bath with a precision thermometer before relaxing in it at the end of his day's work. One terrible evening not so long ago, the captain found his bath to be only 36.8°C. His noble countenance glowed with fury as he ordered his trembling valet to move his portable 80-liter tub from his private dressing tent to the foot of the high-dive ladder. For a moment he paused, deep in thought, and then, ignoring the murmurs of the gathering crowd, he mounted the vertical ladder, counting the rungs as he climbed. He stopped at what was obviously a critical height. Disdainfully he let his dressing gown fall to the spellbound throng far below, and launched himself into the air, landing in his tub with such infinite precision that nary a drop of water was lost from the tiny splash. A smile lighted his features as he relaxed in his 37°C tub, while his valet quickly wheeled him back to his tent. Captain Schultz is 170 cm tall, has blond hair, blue eyes, weighs 70 kg and neglects air resistance. How high did he climb?

6) a. A steel ball weighing 50 kg is dropped through an evacuated vertical tube from a height of 10 m to soft ground at sea level. After the ball comes to rest, what change in total energy has it undergone? What has happened to this energy? What is the change in energy of the ground which the ball struck? In what form is this energy present? What is the change in energy of the ball and the surroundings as a result of this process?

b. The same ball is partially counterbalanced by a 25-kg weight initially on the ground and attached to a weightless, taut rope passing over a frictionless pulley. The ball is again allowed to descend a distance of 10 m to the ground. Answer the same questions of part a for these conditions. Could the 25-kg weight be used to raise the ball? If so, describe the process, and calculate the maximum height to which the ball could be raised.

c. The ball is now suspended 10 m above the ground by a weightless rope wound around a drum equipped with a friction brake. The brake is slightly loosened, and the ball is allowed to descend very slowly to the ground. Answer the same questions of part a for this case. To what body has energy been transferred? What is the final form of this energy?