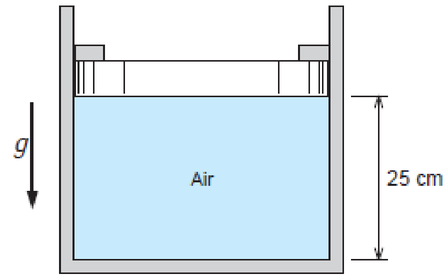
# Midterm Exam # 2

## Fall 2014

## Round-off all numbers of your answer into reasonable digits

**1.** A piston - cylinder arrangement contains air at 250 kPa and 300ºC. The 50-kg piston has a diameter of 0.1 m and initially pushes against the stops. The atmosphere is at 100 kPa and 20ºC. The cylinder now cools as heat is transferred to the ambient surroundings.




- **a. At what temperature does the piston begin to move down?**
- **b. How far has the piston dropped when the temperature reaches the ambient temperature?**
- **c. Show the process on the p–v and the T–v diagrams.**

a. The piston begins to move when the pressure inside is the same as that corresponds to the atmospheric pressure plus the pressure due to piston weight. From force balance:

$$p_{atm} + \frac{mg}{A} = p_2$$

$$10^5 + \frac{50 * 9.81}{\pi * 0.05^2} = p_2 = 162452\ Pa = 1.62\ bar$$

The equation of state at state 1 & 2

$$p_1V_1 = mRT_1 \qquad \& \qquad p_2V_2 = mRT_2$$

The mass and the volume of air is constant form states 1 & 2, therefore:

$$\frac{p_1}{p_2} = \frac{T_1}{T_2}$$

$$\boldsymbol{T_2} = (300 + 273) * \frac{1.62}{2.5} = \mathbf{372\ K = 99}℃$$

b. The equation of state at state 1 & 3

$$p_1V_1 = mRT_1 \qquad \& \qquad p_3V_3 = mRT_3$$

The mass of air is constant form states 1 & 3 and $p_3 = p_2$, therefore:

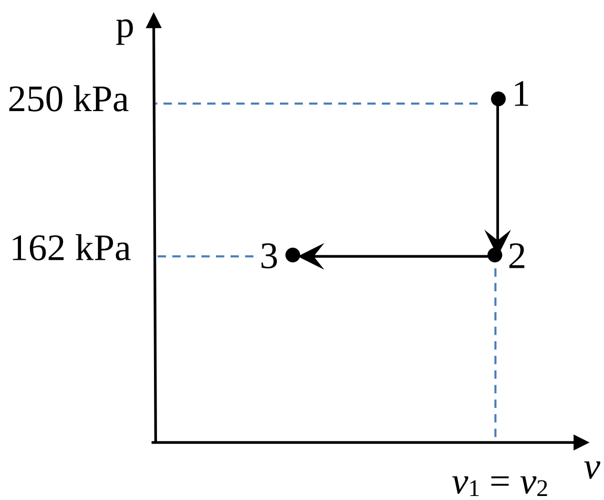
$$\frac{p_1 V_1}{p_3 V_3} = \frac{T_1}{T_3}$$

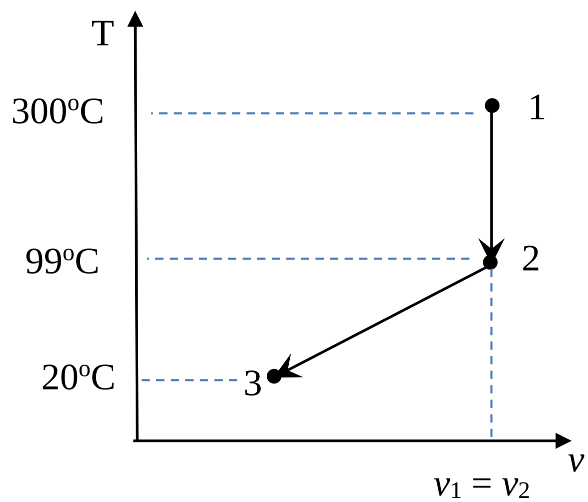
$$\frac{250 * (A_{piston} * 25)}{162 * (A_{piston} * H_3)} = \frac{573}{(20 + 273)}$$

$$\boldsymbol{H_3 = 19.7\ cm}$$

**The piston will drop 5.3 cm**

c.

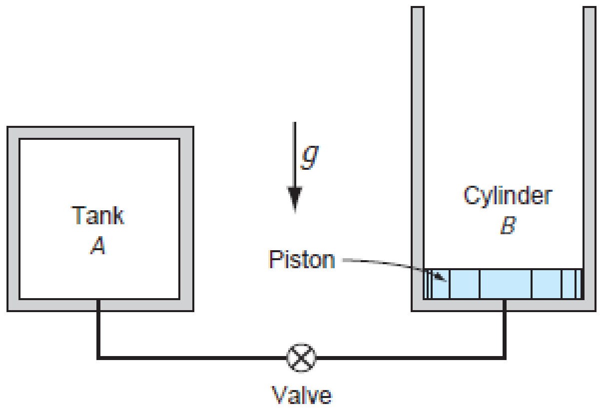


**2.** A 3.5-$m^3$ rigid tank has air at 15 bar and ambient 300 K connected by a valve to a piston-cylinder. The piston of area 0.1 $m^2$ requires 3 bar below it to start raising. The valve is opened, the piston moves slowly 2 m up, and the valve is closed. During the process, air temperature remains at 300 K.

**a. What is the mass of the piston?**

**b. What is the final pressure in the tank?**




a. The mass of the piston will be obtained from the force balance during its motion under constant pressure:

$$p_{atm} + \frac{mg}{A} = 3 * 10^5$$

$$10^5 + \frac{m * 9.81}{0.1} = 3 * 10^5$$

$$\boldsymbol{m = 2039\ kg}$$

b. The mass transferred to the cylinder:

$$p_c V_c = m_c R T_c$$

$$3 * 10^5 * (2 * 0.1) = m_c * 287 * 300$$

$$m_c = 0.7\ kg$$

This mass comes from tank A, therefore, the mass of tank A will decrease by the same amount of 0.7 kg. For tank A:

$$p_{A_1} V_{A_1} = m_{A_1} R T_{A_1} \quad \rightarrow \quad 15 * 10^5 * 3.5 = m_{A1} * 287 * 300$$

$$m_{A1} = 61\ kg$$

$$p_{A_2} V_{A_2} = m_{A2} R T_{A_2}$$

$$\frac{p_{A_1}}{p_{A_2}} = \frac{m_{A_1}}{m_{A2}} = \frac{61}{61 - 0.7}$$

$$\boldsymbol{p_{A2} = 14.8\ bar}$$