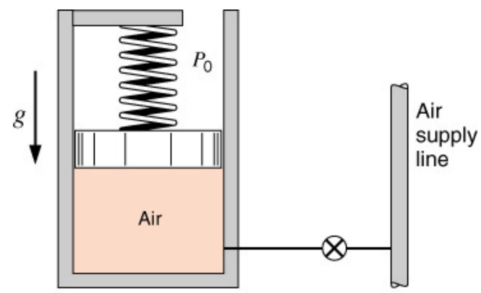
Thermodynamics (ES 340) Quiz 1 May 24, 2005
Name: (1 Hour)

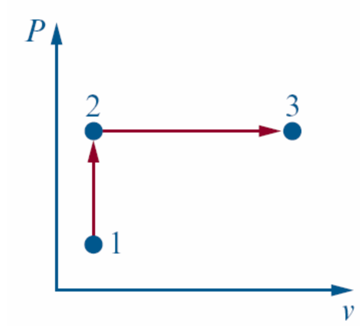
Problem 1 (6 points): A 5-kg piston in a cylinder with diameter of 100 mm is loaded with a linear spring and the outside atmospheric pressure of 100 kPa. The spring exerts no force on the piston when it is at the bottom of the cylinder and for the state shown, the pressure is 400 kPa with volume 0.4 L. The valve is opened to let some air in, causing the piston to rise 2 cm. If the system is assumed to be closed and pressure and volume are linearly related

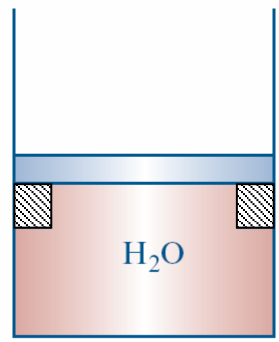
1. Find the pressure when the force from spring is zero (2 points)
2. Draw the P-v diagram (2 points)
3. Find the final pressure. (2 points)
4. **(Bonus)** Find the spring constant (2 points)



Problem 2 (9 points): Water of mass 1 kg at 0.2 MPa is initially enclosed within a volume of 0.10 m^3, and the piston rests on the stops. The piston will move when the pressure is 1.0 MPa. A total heat transfer of 2500 kJ is added to the water. The internal energy of the water at state 1 is 730.96 kJ/kg and it increased due to heat transfer to 1693.5 kJ/kg at state 2. If the specific volume at state 3 is 0.3215 m^3/kg, determine

1. The heat transfer for each process (3 points)
2. The work done by each process and the net work (4 points)
3. Internal energy of water at state 3. (2 points)





Problem 1

given:

$m_p = 5\ Kg$

$d_p = 0.1\ m \longrightarrow A_p = \frac{\pi}{4}(d_p)^2 = \frac{3.1415}{4}(0.1)^2 = 0.007854\ m^2$

$P_{atm} = 100\ Kpa$

State 0:

$\begin{cases} P_0 = ? \\ \forall_0 = 0\ m^3 \end{cases}, \quad F_s = 0$

State 1:

$\begin{cases} P_1 = 400\ Kpa \\ \forall_1 = 0.4\ lit \end{cases}$

State 2:

$P_2 = ? \qquad \Delta\forall = A_p \cdot \Delta x = 0.007854 \times 2\times10^{-2} = 1.571\times10^{-4}\ m^3 = 0.1571\ lit$

$\forall_2 = \forall_1 + \Delta\forall = 0.4 + 0.1571 = 0.5571\ lit$

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(1)

$\Sigma F_x = 0 \xrightarrow{F_s = 0} P_{atm}A + m_p g = P_0 A \rightarrow P_0 = P_{atm} + \frac{m_p g}{A_p}$

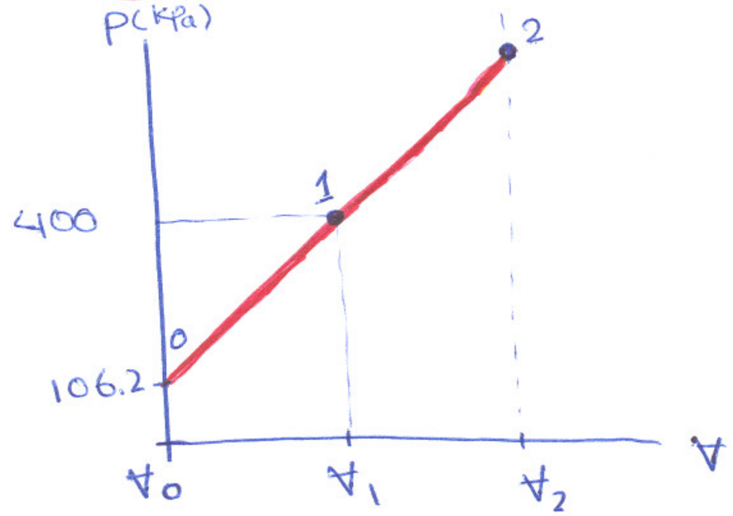
$= 100 + \frac{5\times9.81}{0.00785}$

$= \boxed{106.2\ Kpa}$

(1)

Problem 1 (Cont.)

(2)



(2)

(3) Using the P-∀ diagram

given

$P_0, \forall_0$

$P_1, \forall_1$ } find → P_3 linear interpolation

$\forall_2$

$$\frac{P_2 - P_0}{P_1 - P_0} = \frac{\forall_2 - \forall_0}{\forall_1 - \forall_0}$$

$$\rightarrow P_2 = P_0 + (P_1 - P_0)\left(\frac{\forall_2 - \forall_0}{\forall_1 - \forall_0}\right)$$

$$= 106.2 + (400 - 106.2)\left(\frac{0.5571 - 0}{0.4 - 0}\right)$$

$$= 515.39 \text{ Kpa}$$

(2)

(4) State 1: $F_{S1} + P_{atm} A_p + m_p g = P_1 A_p$

State 2: $F_{S2} + P_{atm} A_p + m_p g = P_2 A_p$

Substract → $K \Delta x = (P_2 - P_1) A_p$

$$\rightarrow K = (515.39 - 400)\left(\frac{0.00785}{0.02}\right)$$

$$= 45.29 \text{ KN/m}$$

Problem 2

given:

$m = 1\ kg$

State ①

$P_1 = 0.2\ Mpa$

$V_1 = 0.1\ m^3$

$u_1 = 730.96\ KJ/kg$

ΣQ or $Q_{13} = 2500\ KJ$

Assumptions: $\Delta PE, \Delta KE = 0$

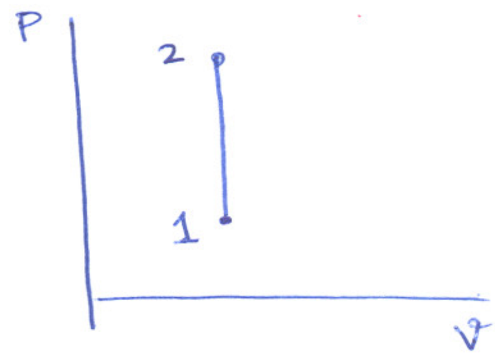
State ②

$P_2 = 1\ Mpa$

$u_2 = 1693.5\ KJ/kg$

State ③

$v_3 = 0.3215\ m^3/kg$



(1) process 1-2

Constant Volume process

→ Balance of Energy:

$\Delta E = Q - W \rightarrow \Delta PE + \Delta KE + \Delta U = Q - W$

$\rightarrow \Delta U_{12} = Q_{12} - W_{12}$ (I)

$W_{12} = \int_1^2 p\,dV \xrightarrow{dV=0} 0$

pluging into (I) $m(u_2 - u_1) = Q_{12} - 0 \rightarrow Q_{12} = 1(1693.5 - 730.96)$

$\rightarrow Q_{12} = 962.54\ KJ$

$Q_{13} = \Sigma Q = Q_{12} + Q_{23} \rightarrow Q_{23} = Q_{13} - Q_{12} = 2500 - 962.54$

$\rightarrow Q_{23} = 1537.46\ KJ$ (1)

Problem 2 (Cont.)

For process 2-3

Balance of Energy:

$$\Delta E = Q - W \longrightarrow \cancel{\Delta PE}^{0} + \cancel{\Delta KE}^{0} + \Delta U = Q_{23} - W$$

$$\xrightarrow{P\_23} m(u_3 - u_2) = Q_{23} - W_{23}$$

$$W_{23} = \int_{\forall_2}^{\forall_3} P\, d\forall = P_2 \int_{\forall_2}^{\forall_3} d\forall = P_2(\forall_3 - \forall_2)$$

$$= 1 \times 10^3 \text{ Kpa} (0.3215 - 0.1)$$

$$= 221.5 \text{ KJ}$$ (2)

$$\rightarrow m(u_3 - u_2) = Q_{23} - W_{23}$$

$$1(u_3 - 1693.5) = 1537.46 - 221.5$$

$$\rightarrow u_3 = 3009.46 \text{ KJ/kg}$$ (3)