Name:____________________

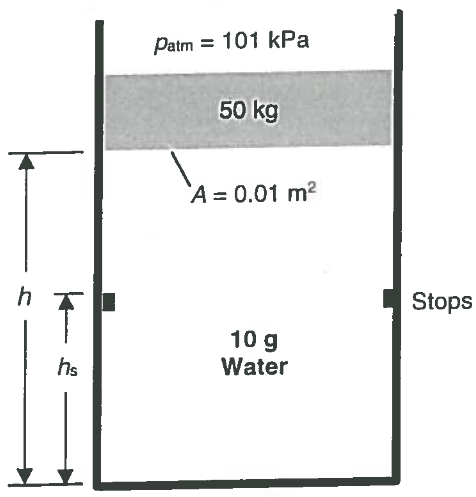
ENGG 311 (Fall 2016)
QUIZ 3

ID:______________

Time Allowed: 30 minutes **24th October 2016**

A mass of 10 g of water at an initial temperature of 400°C in a vertical piston-cylinder assembly (see figure below) is gradually cooled. The piston has a mass of 50 kg, an area of 0.01 m^2 and moves freely in the cylinder with negligible friction. The local atmospheric pressure and acceleration of gravity are 101 kPa and 9.80 m/s^2. As the water is cooled the height of the piston h falls until it reaches the stops, when it can no longer move down. Cooling continues until the temperature reaches 30°C.

a) Assuming that the volume of the stops is negligible, determine the initial height of the piston and the initial pressure of the water.
b) If the quality of the water is 80% when the piston just reaches the stops, determine the height of the stops h_s.
c) Determine the final quality of the water and the total heat and work transfer.
d) Sketch the process on a p-v diagram.



(a) Force balance on the piston:

$P_1 A = P_{atm} A + mg$

$\therefore P_1 = P_{atm} + \frac{mg}{A}$

$P_1 = 101 \frac{kN}{m^2} + \frac{50 \times 9.80 \text{ N}}{0.01 \text{ m}^2} \cdot \frac{1 \text{kN}}{1000 \text{ N}} = 150 \frac{kN}{m^2}$

$P_1 = 150$ kPa or 1.50 bar

TABLE A-4 $T_1 = 400°C$ $P_1 = 1.5$ bar $v_1 = 2.067 \ m^3/kg$.

$h_1 = \frac{V_1}{A} = \frac{m v_1}{A} = \frac{2.067 \times 0.01 \ m^3}{0.01 \ m^2} = 2.067 m$

$h_1 = 2.067$ m. $P_1 = 150$ kPa

(b) $P_2 = P_1$ (Force balance on piston has not changed).

$x_2 = 0.8$ TABLE A3 $P_2 = 1.5$ bar $v_f = 1.0528 \times 10^{-3} \ m^3/kg$, $v_g = 1.159 \ m^3/kg$

$v_2 = x v_g + (1-x) v_f = (0.8 \cdot 1.159 + 0.2 \cdot 1.0528 \times 10^{-3}) = 0.9274 \ m^3/kg$

$h_2 = h_s = \frac{V_2}{A} = \frac{m v_2}{A} = \frac{0.01 \times 0.9274}{0.01} = 0.9274$ m.

$h_2 = h_s = 0.9274$ m.

(c) $h_3 = h_2 = h_s$ $T_3 = 30°C$

$\therefore v_3 = v_2 = 0.9274 \ m^3/kg$

TABLE A-2 $T = 30°C$ $v_f = 1.0043 \times 10^{-3} \frac{m^3}{kg}$ $v_g = 32.894 \frac{m^3}{kg}$.

$v_3 = x_3 v_g + (1-x) v_f$ $\therefore x_3 = \frac{v_3 - v_f}{v_g - v_f}$

$x_3 = \frac{(0.9274 - 1.0043 \times 10^{-3})}{(32.894 - 1.0043 \times 10^{-3})} = 0.02816$ or 2.816%

$x_3 = 0.02816$.

(Continue overleaf if you need more space)

CLOSED SYSTEM: 0.01 kg H_2O.

$$W_{12} = \int_1^2 p\,dV = mp(v_2 - v_1) \qquad W_{23} = 0 \text{ (constant volume)}$$

$$Q_{13} - W_{13} = m(u_3 - u_1) \qquad 1^{st} \text{ LAW} \quad \text{assuming: } (\Delta KE = \Delta PE = 0)$$

$$\therefore Q_{13} = m(u_3 - u_1) + mp(v_2 - v_1)$$

$$W_{13} = W_{12} = 150 \frac{kN}{m^2} \cdot 0.01\,kg\,(0.9274 - 2.067)\frac{m^3}{kg} \cdot \frac{1\,kJ}{1\,kNm}$$

$$\therefore W_{13} = -1.7094\,kJ$$

ie Net work of 1.71 kJ done on the water

TABLE A-2: $T_3 = 30°C$ $\quad u_g = 2416.6\,kJ/kg$, $\quad u_f = 125.78\,kJ/kg$

$$u_3 = [0.02816 \times 2416.6 + (1 - 0.02816) \times 125.78]\,kJ/kg$$

$$u_3 = 190.3\,kJ/kg$$

TABLE A-4 $\quad T_1 = 400°C \quad p_1 = 1.5\,bar : u_1 = 2967.3\,kJ/kg$

$$Q_{13} = 0.01\,kg\,(190.3 - 2967.3)\frac{kJ}{kg} - 1.709\,kJ.$$

$$Q_{13} = -29.48\,kJ$$

ie 29.5 kJ net heat transfer from the water to the surroundings.

(d) p-v diagram: