# Problem Set 6, PS4 due June 2

PS6-1 50 kg of water at 150 kpa and 25 C is contained in a piston cylinder device having a piston cross-sectional area of .1 $m^2$. The water is heated causing part of the water to vaporize. The piston reaches a linear spring having a spring constant of 100 kN/m when the volume contained by the piston cylinder reaches .2 $m^3$ . The piston then rises 20 cm further as more heat is added. Determine using the steam tables and EES a) the final pressure of the water, b) the work done during the processes. Sketch a schematic of the apparatus and a pressure volume property diagram of the processes.

PS6-2 A balloon material has the characteristic that the pressure inside the balloon is always proportional to the square of the diameter. If a spherical balloon made of this material contains 10 lbs of air at 30 psia and 800 R determine the work done when the volume of the balloon doubles as a result of heat transfer.

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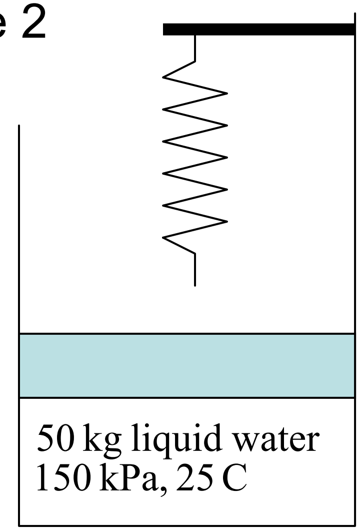


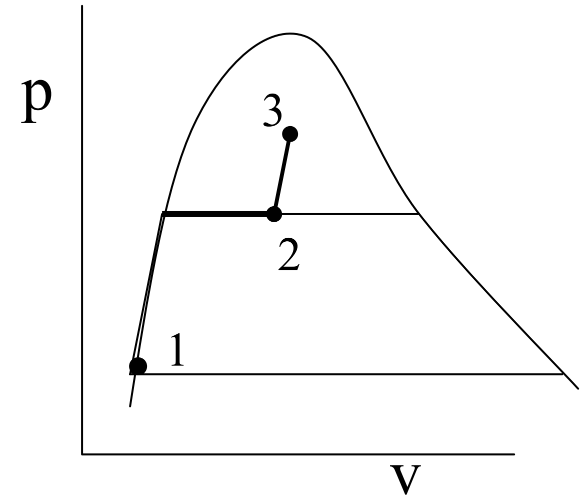


PS6-1

$$v_1 = v_f @ 25^{O}C = .001003\ m^3/kg$$

$$V_1 = m \times v_1 = 50\ kg \times .001003\ m^3/kg = .05\ m^3$$

$$\text{a)}\ \ p_3 = p_2 + \frac{kx}{A} = 150\ kPa + \frac{100\ N/m \times .2\ m}{.1\ m^2}$$

$$p_3 = 150\ kPa + 200\ kPa = 350\ kPa$$

$$v_2 = \frac{.2\ m^3}{50\ kg} = .004\ m^3/kg$$

$$V_3 = V_2 + .1\ m^2 \times .2\ m = .22\ m^3$$

$$v_3 = \frac{V_3}{m} = \frac{.22}{50} = .0044\ m^3/kg$$

$T@P = 350\ kPa$ and $v = .0044\ m^3/kg$ PressureTable
$= 138.88^{O}C$, in two phase region

$$\text{b)}W = m\int_1^2 p\,dv + \int_2^3 F\,dx = m\,p_1(v_2 - v_1) + \int_0^{.2m} (p_2 A + kx)\,dx$$

$$W = m\,p_1(v_2 - v_1) + p_2 \times A \times x + \frac{k \times x^2}{2}$$

$$W = 50 \times 150(.004 - .001003) + 150 \times .1 \times .2 + \frac{100\ N/m}{2}(.2\ m)^2$$

$$W = 22.48 + 3 + 2 = 27.48\ kJ$$

b)alternate = area under straight process line

$$W = m\,p_1(v_2 - v_1) + \frac{(p_3 + p_2)}{2} \times (V_3 - V_2)$$

$$W = 50 \times 150(.004 - .001003) + \frac{(350 + 150)}{2} \times (.22 - .20)$$

$$W = 22.48 + 5 = 27.48\ kJ$$

"PS2 mae 204 Summer 2010"

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## PS6-1

```
"INPUT"
T1=25
p1=150
k=100
V2=.2
m=50
x23=.2
A=.1

"CALCULATION"
sv1=volume(Steam_IAPWS,T=T1,p=p1)
V1=m*sv1
p3=p1+k*x23/A
sv2=V2/m
V3=V2+.1*x23
sv3=V2/m
T3=temperature(Steam_IAPWS,v=v3,p=p3)

p2=p1
W1=m*p1*(sv2-sv1)
w2=+p2*x23*A
w3=(k*x23^2)/2
```

SOLUTION

**Unit Settings: [kJ]/[C]/[kPa]/[kg]/[degrees]**

| | | | | |
|---|---|---|---|---|
| A = 0.1 | k = 100 | m = 50 | p1 = 150 | p2 = 150 |
| p3 = 350 | sv1 = 0.001003 | sv2 = 0.004 | sv3 = 0.004 | T1 = 25 |
| T3 = 138.9 | V1 = 0.05015 | V2 = 0.2 | V3 = 0.22 | W1 = 22.48 |
| w2 = 3 | w3 = 2 | x23 = 0.2 | | |

# Problem Set 6, PS4 due June 2

PS6-2

$$p \propto D^2$$

$$p_1 = C \times D_1^2, \qquad p = C \times D^2$$

$$\frac{p}{p_1} = \frac{C \times D^2}{C \times D_1^2}$$

$$V = \frac{\pi}{6} D^3 \quad \text{Volume of a sphere}$$

$$D = \left(\frac{6}{\pi}\right) V^{\frac{1}{3}}$$

$$p = p_1 \frac{V^{\frac{2}{3}}}{V_1^{\frac{2}{3}}}$$

$$W = \int p\,dV = \int p_1 \frac{V^{\frac{2}{3}}}{V_1^{\frac{2}{3}}} dV = \frac{p_1}{V_1^{\frac{2}{3}}} \int V^{\frac{2}{3}}$$

$$W = \frac{p_1}{V_1^{\frac{2}{3}}} \frac{3}{5} \left( V_2^{\frac{5}{3}} - V_1^{\frac{5}{3}} \right)$$

$$W = \frac{3 \times 30 \times 144}{98.8^{\frac{2}{3}} \times 5} \left( 197.6^{\frac{5}{3}} - 98.8^{\frac{5}{3}} \right) / 778 \ \frac{\text{ft lb}_f}{\text{BTU}}$$

$$W = 717.8 \ \text{BTU}$$

$$p_2 = 30 \times 2^{\frac{2}{3}} = 30 \times 1.587 = 47.6 \text{ psia}$$

$$T_2 = \frac{p\,V_2}{m\,R} = \frac{144 \times 30 \times 1.587 \times 197.6}{10 \times 53.35} = 2539.3 \text{ R}$$

$$\Delta U = 10 \text{ lb}_m \times .208 \text{ BTU/lb}_m \text{ K } (2539.3 - 800) = 36177$$

.208 is the $c_v$ at about average $1500^O$ F

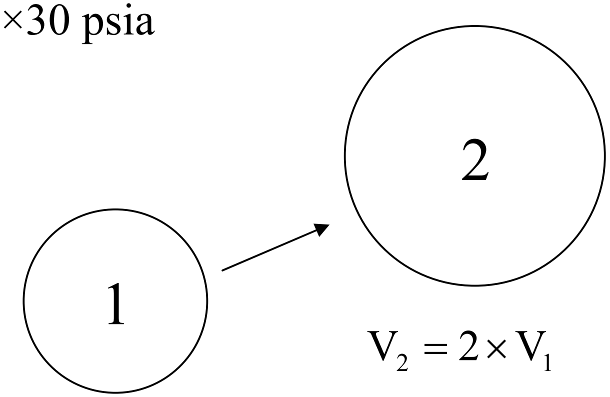
$$Q = \Delta U + W = 36177. + 717 = 36{,}894. \text{ BTU}$$

$$V_1 = \frac{mRT}{p}$$

$$V_1 = \frac{10 \text{ lb}_m \times 53.35 \text{ ft lb}_f / \text{lb}_m F \times 800 \text{ R}}{144 \text{in}^2/\text{ft}^2 \times 30 \text{ psia}}$$

$$V_1 = 98.8 \text{ft}^3$$

$$V_2 = 2 \times V_1 = 197.6 \text{ft}^3$$




$$V_2 = 2 \times V_1$$

10 lb
30 psia
800 K