2

2.1 (a) By an energy balance, the bicycle stops when final potential energy equals initial kinetic energy. Therefore

$$\frac{1}{2}mv_i^2 = mgh_f \quad \text{or} \quad h_f = \frac{v_i^2}{2g} = \frac{\left(20\frac{\text{km}}{\text{hr}}\times 1000\frac{\text{m}}{\text{km}}\times\frac{1\text{ hr}}{3600\text{ sec}}\right)^2}{2\times 9.807\frac{\text{m}}{\text{sec}^2}}$$

or h=1.57 m.

(b) The energy balance now is

$$\frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 + mgh_i \quad \text{or} \quad v_f^2 = v_i^2 + 2gh_i$$

$$v_f^2 = \left(20\ \frac{\text{km}}{\text{hr}}\right)^2 + 2\times 9.807\frac{\text{m}}{\text{sec}^2}\times 70\text{ m}\times\left(\frac{\text{km}}{1000\text{ m}}\times\frac{3600\,\text{sec}}{\text{hr}}\right)^2$$

v_f = 134.88 km/hr. Anyone who has bicycled realizes that this number is much too high, which demonstrates the importance of air and wind resistance.

2.2 The velocity change due to the 55 m fall is

$$\left(\Delta v^2\right) = 2\times 9.807\frac{\text{m}}{\text{sec}^2}\times 55\text{ m}\times\left(\frac{\text{km}}{1000\text{ m}}\times\frac{3600\,\text{sec}}{\text{hr}}\right)^2$$

v_f = 118.24 km/hr. Now this velocity component is in the vertical direction. The initial velocity of 8 km/hr was obviously in the horizontal direction. So the final velocity is

$$v = \sqrt{v_x^2 + v_y^2} = 118.51\frac{\text{km}}{\text{hr}}$$

2.3 (a) System: contents of the piston and cylinder
(closed isobaric = constant pressure)
M.B.: $M_2 - M_1 = \Delta M = 0 \Rightarrow M_2 = M_1 = M$

$$\text{E.B.:}\quad M_2\hat{U}_2 - M_1\hat{U}_1 = \cancel{\Delta M\left(\hat{H}\right)}^{0} + Q + \cancel{W_s}^{0} - \int P dV$$

$$M\left(\hat{U}_2 - \hat{U}_1\right) = Q - \int PdV = Q - P\int dV = Q - P(V_2 - V_1)$$

$$M\left(\hat{U}_2 - \hat{U}_1\right) = Q - PM\left(\hat{V}_2 - \hat{V}_1\right)$$

$$Q = M\left(\hat{U}_2 - \hat{U}_1\right) + M\left(P\hat{V}_2 - P\hat{V}_1\right) = M\left[\left(\hat{U}_2 + P\hat{V}_2\right) - \left(\hat{U}_1 + P\hat{V}_1\right)\right]$$

$$= M\left(\hat{H}_2 - \hat{H}_1\right)$$

$P = 1.013 \text{ bar} \approx 0.1 \text{ MPa}$

	$\hat{V}$	$\hat{U}$	$\hat{H}$	
$T = 100$	1.6958	2506.7	2676.2	
$T = 150$	1.9364	2582.8	2776.4	
Linear interpolation				
$T = 125°\text{C}$	1.8161	2544.8	2726.3	Initial state

Final state $P = 0.1 \text{ MPa}$, $\hat{V}_2 = 3.6322 \text{ m}^3/\text{kg}$

$T = 500°\text{C}$	3.565	3488.1
$T = 600°\text{C}$	4.028	3704.7

Linear interpolation

$$\frac{3.6322 - 3.565}{4.028 - 3.565} = \frac{T_2 - 500}{600 - 500} \qquad T_2 = 514.5°\text{C}$$

$$\frac{514.5 - 500}{600 - 500} = \frac{\hat{H}_2 - 3488.1}{3704.7 - 3488.1} \qquad \hat{H}_2 = 3519.5$$

$$Q = 1 \text{ kg}(3519.5 - 2726.3)\text{ kJ/kg} = 793.2 \text{ kJ}$$

$$W = -\int PdV = -1 \text{ bar} \times (V_2 - V_1) = -1 \text{ bar} \times (3.6322 - 1.8161) \text{ m}^3/\text{kg}$$

$$= -1 \text{ bar} \times 100{,}000 \frac{\text{Pa}}{\text{bar}} \times \frac{1 \text{ kg}}{\text{m} \cdot \text{s}^2 \cdot \text{Pa}} \times \frac{1 \text{ J}}{\text{m}^2 \cdot \text{s}^2 \cdot \text{kg}} \times 1.8161 \text{ m}^3/\text{kg}$$

$$= -181.6 \text{ kJ/kg}$$

(b) System is closed and constant volume

M.B.: $M_2 = M_1 = M$

E.B.: $M_2\hat{U}_2 - M_1\hat{U}_1 = \Delta M(\hat{H})^{\,0} + Q + W_s^{\,0} - \int PdV^{\,0}$

$Q = M(\hat{U}_2 - \hat{U}_1)$

Here final state is $P = 2 \times 1.013 \text{ bar} \sim 0.2 \text{ MPa}$; $\hat{V}_2 = \hat{V}_1 = 1.8161 \text{ m}^3/\text{kg}$ (since piston-cylinder volume is fixed)

$P = 0.2 \text{ MPa}$; $\hat{V}_2 = 1.8161$

$T(°\text{C})$	$\hat{V}$	$\hat{U}$
500	1.7814	3130.8
600	2.013	3301.4

$$\frac{1.8161 - 1.7814}{2.013 - 1.7814} = \frac{T - 500}{600 - 500} = \frac{0.0347}{0.2316} = 0.1498 \sim 0.15$$

$$T = 515°\text{C}$$

$$\frac{\hat{U}_2 - 3130.8}{3301.4 - 3130.8} = 0.1498 \qquad \hat{U}_2 = 3156.4 \text{ kJ/kg}$$

$$Q = 1 \text{ kg} \times (3156.4 - 2544.8) \text{ kJ/kg} = 611.6 \text{ kJ}$$

(c) Steam as an ideal gas—constant pressure

$$N = \frac{P\underline{V}}{RT} \Rightarrow \frac{P_1\underline{V}_1}{RT_1} = \frac{P_2\underline{V}_2}{RT_2} \text{ but } \underline{V}_2 = 2\underline{V}_1;\ P_1 = P_2$$

$$\frac{P_1\underline{V}_1}{T_1} = \frac{P_1 2\underline{V}_1}{T_2} \Rightarrow T_2 = 2\times T_1$$
$$T_1 = 273.15 + 125 = 398.15\ \text{K}$$
$$T_2 = 2\times T_1 = 796.3\ \text{K} = 523.15°\text{C}$$

$$Q = N\Delta\underline{H} = \frac{1000\ \text{g/kg}}{18\ \text{g/mol}} \times 34.4\ \text{J/mol K} \times (796.3 - 398.15)\ \text{K} \times \frac{1\ \text{kJ}}{1000\ \text{J}}$$
$$= 760.9\ \text{kJ}$$
$$W = -\int PdV = -P\Delta V = -P\left(\frac{NRT_2}{P} - \frac{NRT_1}{P_1}\right) = -NR(T_2 - T_1)$$
$$= -\frac{1000}{18}\times 8.314 \times 398.15 = -183.9\ \text{kJ}$$

(d) Ideal gas - constant volume

$$\frac{P_1\underline{V}_1}{RT_1} = \frac{P_2\underline{V}_2}{RT_2}\ \text{ here }\ \underline{V}_1 = \underline{V}_2;\ P_2 = 2P_1$$

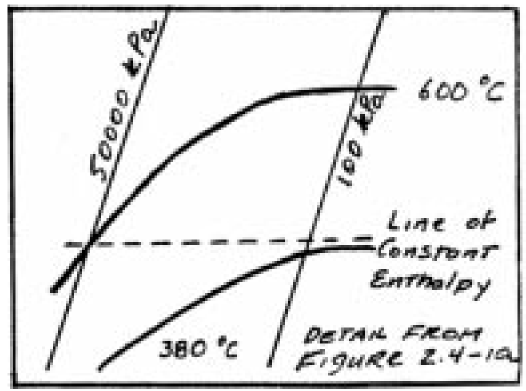
So again $\frac{P_1V_1}{T_1} = \frac{2P_1\cdot V_1}{T_2}$; $T_2 = 2T_1 = 796.3\ \text{K}$.

$$Q = N\Delta\underline{U} = \frac{1000\ \text{g/kg}}{18\ \text{g/mol}} \times (34.4 - 8.314) \times (796.3 - 398.15) \times \frac{1}{1000}$$
$$C_V = C_P - R;\ Q = 577.0\ \text{kJ}$$

2.4

$$M_w\hat{U}_{w,\,f} - M_w\hat{U}_{w,\,i} = W_s = M_{weight}\times g\times 1\ \text{m}$$
$$M_w = M_{weight} = 1\ \text{kg}$$
$$1\ \text{kg}\times C_P(T_f - T_i) = 1\ \text{kg}\times 9.807\ \text{m/s}^2 \times 1\ \text{m}\times\frac{1\ \text{J}}{\text{m}^2\text{kg/s}^2} = 9.807\ \text{J}$$
$$1\ \text{kg}\times 4.184\ \text{J/g K}\times\frac{1000\ \text{g}}{\text{kg}}\times\Delta T = 9.807$$
$$\Delta T = \frac{9.807}{4.184\times 1000}\ \text{K} = 2.344\times 10^{-3}\ \text{K}$$

2.5 From Illustration 2.3-3 we have that $\underline{H}(T_1,\ P_1) = \underline{H}(T_2,\ P_2)$ for a Joule-Thomson expansion. On the Mollier diagram for steam, Fig. 2.4-1a, the upstream and downstream conditions are connected by a horizontal line. Thus, graphically, we find that $T \sim 383\ \text{K}$. (Alternatively, one could also use the Steam Tables of Appendix III.)



For the ideal gas, enthalpy is a function of temperature only. Thus, $\underline{H}(T_1,\ P_1) = \underline{H}(T_2,\ P_2)$ becomes $\underline{H}(T_1) = \underline{H}(T_2)$, which implies that $T_1 = T_2 = 600°\text{C}$.