Chapter 1

1.1

Mass of water $=10^6$g, temperature raised by $20^\circ C$.
Heat needed $Q = 2 \times 10^7$cal $= 8.37\times10^7$J.=23.2 kwh.
Work needed $= mgh = 14\times150\times29000 = 6.09\times10^7$ ft-lb =22.9 kwh.

1.2

Work done along various paths are as follows

ab:

$$\int_a^b PdV = Nk_BT_1 \int_a^b \frac{dV}{V} = Nk_BT_1 \ln\frac{V_b}{V_a}$$

cd:

$$P_d(V_d - V_b) = Nk_BT_3\left(1 - \frac{V_b}{V_d}\right)$$

de:

$$Nk_BT_3 \int_d^e \frac{dV}{V} = Nk_BT_3 \ln\frac{V_a}{V_d}$$

No work is done along bc and ea. The total work done is the sum of the above. Heat absorbed equals total work done, since internal energy is unchanged in a closed cycle.

1.3

(a)

$$\alpha = \frac{1}{V}\frac{\partial V}{\partial T} = \frac{bV_0T^{b-1}}{T_0^bV}$$

(b)

$$\begin{aligned}
\Delta V &= \frac{bV_0T^{b-1}}{T_0^b}\Delta T \\
P &= \frac{Nk_BT}{V} = \frac{Nk_BT_0^b}{V_0}T^{1-b} \\
\text{Work done} &= P\Delta V = bNk_B\Delta T
\end{aligned}$$

1.4

Consider an element of the column of gas, of unit cross section, and height between z and $z+dz$. The weight of the element is $-gdM$, where dM is the mass of the element: $dM = mndz$, where m is the molecular mass, and $n = P/k_BT$ is the local density, with P the pressure. For equilibrium, the weight must equal the pressure differential: $dP = -gdM$ .Thus, $dP/P = -(mg/k_BT)dz$. At constant T , we have $dp/P = dn/n$.Therefore

$$n(z) = n(0)e^{-mgz/k_BT}$$

1.5

No change in internal energy, and no work is done. Therefore total heat absorbed $\Delta Q = \Delta Q_1 + \Delta Q_2 = 0$. That is, heat just pass from one body to the other. Suppose the final temperature is T. Then

$\Delta Q_1 = C_1(T - T_1)$, $\Delta Q_2 = C_2(T - T_2)$. Therefore

$$T = \frac{C_1T_1 + C_2T_2}{C_1 + C_2}$$

1.6

Work done by the system is $-\int HdM$. Thus the work on the system is

$$\int HdM = \frac{\kappa}{T}\int HdH = \frac{\kappa H^2}{2T}$$

1.7

Consider the hysteresis cycle in the sense indicated in Fig.1.6. Solve for the magnetic field:

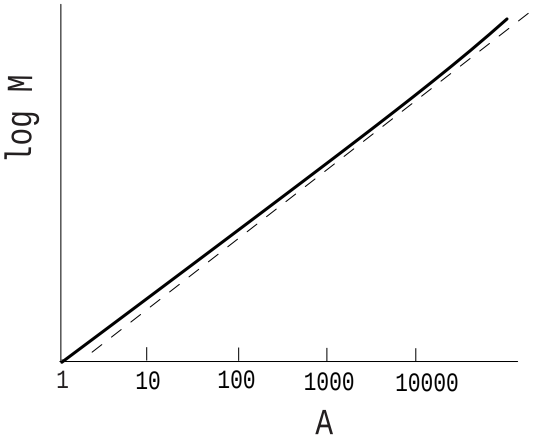
$$H = \pm H_0 + \tanh^{-1}(M/M_0)$$

(+ for lower branch, − for upper branch.). Using $W = -\int HdM$, we obtain

$$\begin{aligned} W &= -\int_{-M_0}^{M_0} dM[H_0 + \tanh^{-1}(M/M_0)] - \int_{M_0}^{-M_0} dM[-H_0 + \tanh^{-1}(M/M_0)] \\ &= -4M_0H_0 \end{aligned}$$

1.8

A log log plot of mass vs. A is shown in the following graph. The dashed line is a straightline for reference.



.

Chapter 2

2.1

Use the dQ equation with P, T as independent variables:
$dQ = C_P dT + [(\partial U/\partial P)_T + P(\partial V/\partial P)_T]dP$
For an ideal gas $(\partial U/\partial P)_T = 0$, $P(\partial V/\partial P)_T = -V$. Thus
$dQ = C_P dT - V dP$.
The heat capacity is given by
$C = C_P - V(\partial P/\partial T)_{\text{path}}$.
The path is $P = aV^b$, or equivalently $P^{b+1} = a(Nk_BT)^b$ by the equation of state. Hence
$V(\partial P/\partial T)_{\text{path}} = [ab/(b+1)]V(Nk_BT)^bT^{-1} = bNk_B/(b+1)$. Therefore

$$C = C_P - \frac{b}{b+1}Nk_B$$

This correctly reduces to C_P for $b = 0$.

2.2

Use a Carnot engine to extracted energy from 1 gram of water between 300 K and 290 K.

Max efficiency $\eta = 1 - (290/300) = 1/30$.

$$W = \eta C\Delta T = \frac{1}{30}(4.164 \text{ J g}^{-1}\text{K}^{-1} \times 1 \text{ g} \times 10 \text{ K}) = 1.39 \text{ J}$$

$$\text{Gravitational potential energy} = 1 \text{ g} \times 9.8 \text{ kg s}^{-2} \times 110 \text{ m} = 1.08 \text{ J}$$

2.3

The highest and lowest available temperatures are, 600 F = 588.7 K and 70 F = 294.3 K.

The efficiency of the power plant is $W/Q_1 = 0.6[1 - (294.3/588.7)] = 0.3$.
In one second: $W = 10^6$ J.
So $Q_2 = 2.33 \times 10^6$ J $= C_V\Delta T$. Use $C_V = 4.184$ J g^{-1}K^{-1},