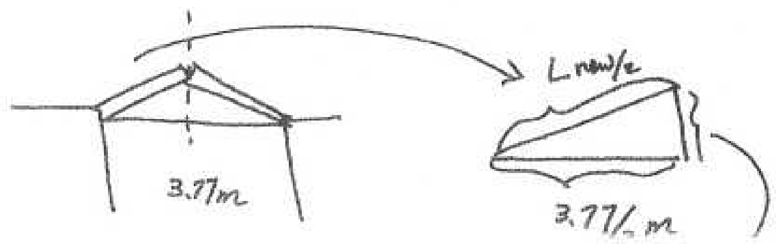
ch 18. #21, 30, 37, 3, 41, 42, 43, 44, 45, 48, 49, 54, 59

#21

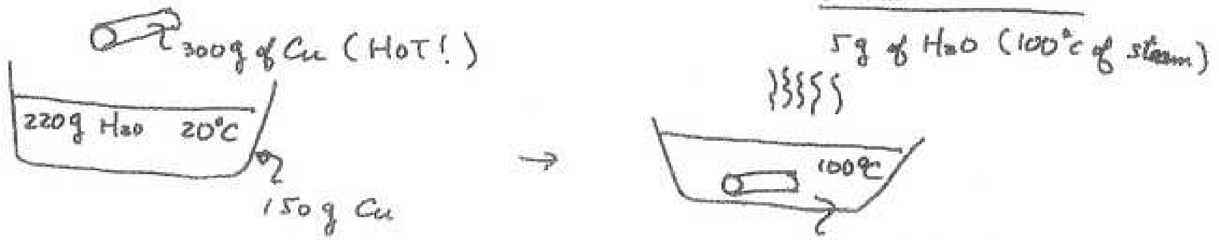


$\Delta T = 32°C$
$\alpha = 25 \times 10^{-6}/°C$

$L_{new} = L + L\alpha\Delta T$
$= 3.773016\,m$

$$\left[\left(\frac{3.773016}{2}\right)^2 - \left(\frac{3.77}{2}\right)^2\right]^{1/2} = 0.07541578\,m$$
$$= \underline{\underline{7.541578\,cm}}$$

#30



(a)

ΔQ_{H_2O} = E(220g of water brought from 20°C → 100°C) + E(5g of water brought from 100°C of water to 100°c of steam)

$= (SHC \cdot mass \cdot \Delta T)_{H_2O} + L_V \cdot mass$

$= 1\,cal/g/°C \cdot 220g \cdot (100-20)°C + 538.939...\,cal/g \cdot 5g$

$= 17600\,cal + 2694.696608\,cal$

$= \underline{\underline{20294.69611\,cal}}$

$L_V = 2256\,KJ/kg$
$= 2256\,J/g$
$= 538.9393215\,cal/g$

(b)

$\Delta Q_{Cu} = SHC_{Cu} \cdot mass \cdot \Delta T$

$= 0.0923\,cal/g/°C \cdot 150g \cdot (100-20)°C$

$= \underline{\underline{1107.6\,cal}}$

(c)

$+\Delta Q$ to H_2O & Cu bowl $-$ Q from the Cu Cylinder $= 0$.

$(20294.69611\,cal + 1107.6\,cal) - 0.0923\,cal/g/°C \cdot 300g \cdot \Delta T$

$$\Delta T = \frac{21402.29661\,cal}{0.0923\,cal/g/°C \cdot 300g} = 772.9251213°C \text{ (from } T_f = 100°C)$$

$\therefore T_i = \Delta T + T_f = 872.9251213°C$

#37

(a) First we need to check 500 g of 90°C water has enough energy to melt 500 g of 0°C ice.

$$\left[\begin{array}{l} SHC_{H_2O} = 4.190\ J/g/°C \\ L_F = 333\ J/g \end{array}\right]$$

Energy above 0°C (for 90°C water)

$4.190\ J/g/°C \cdot 500g \cdot 90°C$

$= 1.8855 \times 10^{5}\ J$

Energy needed to melt 0°C ice

$L_F \cdot mass$

$333\ J/g \cdot 500g$

$= 1.665 \times 10^{5}\ J$

As you can see, the 90°C water has barely enough to melt all ice. The left over energy is shared by (500g + 500g) of water at the same temperature.

$$\therefore \quad (1.8855 \times 10^{5} J - 1.665 \times 10^{5} J) = 4.190\ J/g/°C \cdot (500g + 500g)\ T_f$$

$$T_f = \frac{(1.8855 \times 10^{5} J - 1.665 \times 10^{5} J)}{4.190\ J/g/°C \cdot 1000g} = \underline{\underline{5.2625298\dot{3}3\ °C}}$$

(b)

Energy above 0°C (for 70°C water)

$4.190\ J/g/°C \cdot 500g \cdot 70°C$

$= 1.46650 \times 10^{7}\ J$ (This is not enough to melt all the ice!)

How many grams of ice can this energy melt?

$1.46650 \times 10^{7} J \div 333\ J/g = \underline{440.3\dot{9}0\dot{3}9\dot{0}4\ g}$

So, unmelted ice is 500 g − ↙ = $\underline{\underline{59.\ddot{6}9\ g}}$

#39

$(SHC_{ice} = 2220\ J/g/°C)$

Energy of H_2O above 0°C

$4.190\ J/g/°C \cdot 200g \cdot 25°C$

$= 20950\ J$

Energy of ice below 0°C water level

$2.220\ J/g/°C \cdot (50g \times 2) + 333\ J/g/°C \cdot (50g \times 2)$

$= 3330\ J + 33300\ J$

$= 36630\ J$

(a) $E_T = -15680\ J$ (15680 J lower than 0°C water level)

$15680\ J \div 333\ J/g = 47.\dot{0}8\dot{7}\ g$ (to freeze ice)

$\Rightarrow$ $\underline{\underline{47.\dot{0}8\dot{7}\ g \text{ of } 0°C \text{ ice } \& \ 252.\dot{9}1\dot{2}\ g \text{ of } 0°C \text{ water}}}$

(b) 50g of ice instead of 100g.

Energy of ice below 0°C water level

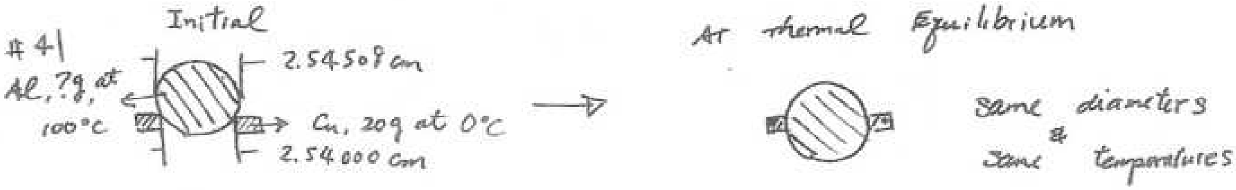
$2.22\ J/g/°C \cdot 50g + 333\ J/g/°C \cdot 50g$

$= 1665\ J + 16650\ J = 18315\ J$

$E_T = 20950J - 18315J = 2605\ J$ (This is shared by (200+50)g water)

$2605\ J \div (4.190\ J/g/°C \cdot 250g) = $ [illegible] °C

#41



. thermal Expansion

Dia. of Cu = Dia. of Al (at thermal equilibrium)

$$L_{cu} + L_{cu}\alpha_{cu}\Delta T = L_{Al} + L_{Al}\alpha_{Al}\Delta T$$

$$\begin{bmatrix} \alpha_{cu} = 17\times10^{-6}/°C \\ \alpha_{Al} = 23\times10^{-6}/°C \\ SHC_{cu} = 0.0923\ cal/g/°C \\ SHC_{Al} = 0.215\ cal/g/°C \end{bmatrix}$$

$$2.54000\,cm + 2.54cm \cdot 17\times10^{-6}/°C\,(T_f - \cancel{T_{i,cu}}) = 2.54508cm + 2.54508cm \cdot 23\times10^{-6}/°C\,(T_f - \overset{100°C}{T_i})$$

$$2.54 + 2.54 \cdot 17\times10^{-6}/°C \cdot T_f = 2.54508 + 2.54508 \cdot 23\times10^{-6}T_f - 254.508 \cdot 23\times10^{-6}/°C$$

Solve for T_f

$$T_f = \frac{2.54 - 2.54508 + 254.508 \cdot 23\times10^{-6}}{2.54508 \cdot 23\times10^{-6} - 2.54 \cdot 17\times10^{-6}} = \underline{50.81397787\ °C}$$

cons. of E

$$E_i \qquad\qquad E_f$$

$$SHC_{cu} \cdot m_{cu} \cdot \cancel{\overset{0}{T_{i,cu}}} + SHC_{Al} \cdot m_{Al} \cdot \overset{100}{T_{i,Al}} = (SHC_{cu} \cdot m_{cu} + SHC_{Al} \cdot m_{Al})T_f$$

$$100\ SHC_{Al} \cdot m_{Al} - SHC_{Al} \cdot m_{Al}\,T_f = SHC_{cu} \cdot m_{cu} \cdot T_f$$

$$(100 - T_f)\ SHC_{Al} \cdot m_{Al} = SHC_{cu} \cdot m_{cu} \cdot T_f$$

$$\therefore m_{Al} = \frac{SHC_{cu} \cdot m_{cu} \cdot T_f}{(100 - T_f)\ SHC_{Al}}$$

$$= \frac{0.0923 \cdot 20 \cdot 50.81397787}{(100 - 50.81\ldots)\ 0.215}$$

$$= 8.870226918\ g$$

#42 (a)

	Q	W	ΔE
A → B	+	+	+
B → C	+	0	+
C → A	—	—	—

W is + because it moved to +
Q is + because $\Delta E = Q - W$
W is 0 because it went up straight (No vol change)
E is + because $\Delta E = Q$
W is — because it moved to —
ΔE is — because it has to come back to the same state
Q is — because $\Delta E = Q - W$.

(b)

A → B	40 J
B → C	0
C → A	−60 J
Net	<u>−20 J</u> (outside did 20 J of work to the system)

#43

Calculate the area enclosed by path A, B or C

$\left(W = \int_{Vol_i}^{Vol_f} Pr \cdot d(vol) \right)$

A: $40\,(4-1) = \underline{120\text{ J}}$

B: $120\text{ J} - 45\text{ J} = \underline{75\text{ J}}$

C: $10\,(4-1) = \underline{30\text{ J}}$

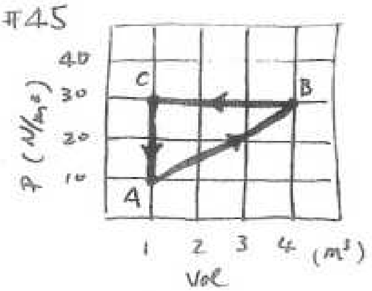
#44

(a) $W = \underline{-200\text{ J}}$

(b) $Q = -70\text{ cal} = \underline{-293.02\text{ J}}$

(c) $\Delta E_{int} = Q - W = \underline{-93.02\text{ J}}$

#45



As you can see $\overline{AB}$ is the time when the positive work is done to the system, and $\overline{BC}$ is when the system is doing the work (Energy is going out). No work is done during $\overline{CA}$. Also notice that the system is releasing more energy to outside ($\overline{BC}$ phase) than taking ($\overline{AB}$ phase). The net change is the area of the triangle ABC.

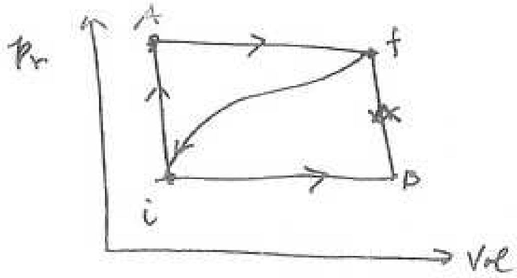
$\therefore \frac{1}{2}(30-10)(4-1)$ J or −30 J of work is done to the system or 30 J of work is done to the outside by the system.

#48 $Q_{AB} + Q_{BC} + Q_{CA} = W$

$\therefore Q_{CA} = W - Q_{AB} - Q_{BC}$

$= 15\,J - 20\,J - 0\,J = \underline{\underline{-5\,J}}$ (the system emits 5 J to outside)

#49



iaf $\quad Q = 50\,cal$, $W = 20\,cal$

ibf $\quad Q = 36\,cal$, $W = ?$

(a) No matter which path it takes ΔE_{int} from "i" & "f" should be the same.

using iaf : $\Delta E_{int} = Q - W = 50\,cal - 20\,cal = 30\,cal.$

so, using ibf, $\Delta E_{int} = 30\,cal.$

$\therefore \quad \Delta E_{int} = 30\,cal = Q - W = 36\,cal - W$

$\therefore \underline{\underline{W = 6\,cal}}$

(b) Going back to "i" from "f", $\Delta E = -30\,cal$ (reverse of (a))

$-30\,cal = Q - (-13\,cal)$

$\therefore \underline{\underline{Q = -43\,cal}}$

(c) $E_{ib} = 22\,cal$

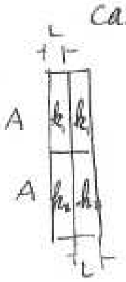
$\Delta E = E_{ib} + E_{bf}$

$30\,cal = 22\,cal + E_{bf}$

$\therefore \underline{\underline{E_{bf} = 18\,cal = Q}}$ because $E_{bf} = Q_{bf} - W_{bf}$ & $W_{bf} = 0$ (No vol change)

\# 54

case (a)

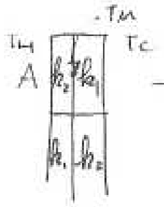


$$\rightarrow \quad P_1 = k_1 \frac{A(T_H - T_C)}{2L}$$

$$\rightarrow \quad P_2 = k_2 \frac{A(T_H - T_C)}{2L}$$

$$P_T = P_1 + P_2 = \underline{(k_1 + k_2)\frac{A(T_H - T_C)}{2L}} \quad — ①$$

case (b)



$$\rightarrow \quad P = k_2 \frac{A(T_H - T_M)}{L} = k_1 \frac{A(T_M - T_C)}{L}$$

Solve for T_M

$$k_2(T_H - T_M) = k_1(T_M - T_C)$$

$$T_M = \frac{k_2 T_H + k_1 T_C}{k_1 + k_2} \quad \Rightarrow \text{sub. back to the 1st eqn.}$$

$$\therefore P = k_2 \frac{A\left(T_H - \frac{k_2 T_H + k_1 T_C}{k_1 + k_2}\right)}{L}$$

$$= \frac{k_2 A}{L}\left(T_H(k_1 + k_2) - (k_2 T_H + k_1 T_C)\right)$$

$$= \underline{\frac{A}{L} \frac{k_1 k_2 (T_H - T_C)}{k_1 + k_2}} \quad \Rightarrow \quad P_T = 2 \times P = \underline{\frac{2A}{L} \frac{k_1 k_2 (T_H - T_C)}{k_1 + k_2}} \quad —②$$

①

$$\frac{(k_1 + k_2)}{2} \cdot \frac{A(T_H - T_C)}{L}$$

②

$$\frac{2 k_1 k_2}{(k_1 + k_2)} \cdot \frac{A(T_H - T_C)}{L}$$

So which is bigger?

$$\left(\frac{k_1 + k_2}{2}\right) - \left(\frac{2 k_1 k_2}{k_1 + k_2}\right) \overset{?}{\gtrless} 0$$

$$\frac{k_1 + k_2}{2} \overset{?}{\gtrless} \frac{2 k_1 k_2}{k_1 + k_2}$$

$$(k_1 + k_2)^2 - 4 k_1 k_2$$

$$= k_1^2 + k_2^2 - 2 k_1 k_2$$

$$= (k_1 - k_2)^2 > 0 \quad (k_1 \neq k_2)$$

$$\therefore \underline{P_{case\,(a)} > P_{case\,(b)}}$$

#59

k_1 (0.06 W/m·K), L_1 (1.5 cm); 30°C →| ←25°C; k_2, L_2; k_3 (0.04 W/m·K), L_3 (2.8 cm); ← T; k_4 (0.12 W/m·K), L_4 (3.5 cm); ← −10°C

Key sentence: Energy transfer through the wall is steady

$$\therefore \quad P_{cond} = k_1 A \frac{(T_H - T_{C,1})}{L_1} = k_4 A \frac{(T - T_{C,4})}{L_4}$$

$$k_1 \frac{(T_H - T_{C,1})}{L_1} = k_4 \frac{(T - T_{C,4})}{L_4}$$

$$\therefore \quad T = T_C + \frac{k_1 L_4}{k_4 L_1}(T_H - T_{C,1})$$

Chapter 18 additional problems $\quad = -10^\circ C + \frac{0.06 \cdot 3.5\,cm}{0.12 \cdot 1.5\,cm}(30^\circ C - 25^\circ C) = \underline{-4.16^\circ C}$

#1 The Pyrex glass mirror in the telescope at the Mr. Palomar Observatory has a diameter of 200 inches. The temperature ranges from $-10\ ^0C$ to $50\ ^0C$ on Mt. Palomar. In micrometers, what is the maximum change in the diameter of the mirror, assuming that the glass can freely expand and contract?

#2 The area A of a rectangular plate is "ab". Its coefficient of linear expansion is α. After a temperature rise ΔT, side a is longer by Δa and side b by Δb. Show that if the small quantity $(\Delta a \Delta b)/ab$ is neglected, then $\Delta A = 2\alpha A \Delta T$.

#3 A pendulum clock with a pendulum made of brass is designed to keep accurate time at $20\ ^0C$. If the clock operates at $0.0\ ^0C$, what is the magnitude of its error, in seconds per hour, and does the clock run fast or slow?

#4 How much water remains unfrozen after 50.2 kJ is transferred as heat from 260 g of liquid water initially at its freezing point?

#5 An energetic athlete can use up all the energy from a diet of 4000 Cal/day. If he were to use up this energy at a steady rate, how would his rate of energy use compare with the power of a 100 W bulb?

#6 How many grams of butter, which has a usable energy content of 6.0 Cal/g, would be equivalent to the change in gravitational potential energy of a 73.0 kg man who ascends from sea level to the top of Mt. Everest, at elevation 8.84 km? Assume that the average value of g is $9.80\ m/sec^2$.

#7 Suppose that a man holding a container, and there is water inside. If he is making 30 shakes each minute and the water 30 cm each shake, how long must he shake the container to change water temperature from $15\ ^0C$ to $100\ ^0C$? Neglect any loss of thermal energy by the container.

#8 In a solar water heater, energy from the sun is gathered by water that circulates through tubes in a rooftop collector. The solar radiation energy the collector through a transparent cover and warms the water in the tubes; this water is pumped into a holding tank. Assume that the efficiency of the overall system is 20%. What collector area is necessary to raise the temperature of 200 L of water in the tank from $20\ ^0C$ to $40\ ^0C$ in 1.0 hour when the intensity of incident sunlight is $700\ W/m^2$?

#1 $200\,in = 508\,cm$

$\alpha_{pyrex} = 3.2\times10^{-6}/°c$

$\Delta L = L\alpha\Delta T$

$= (508\,cm)(3.2\times10^{-6}/°c)(50-(-10))°c$

$= 9.7536\times10^{-4}m$

$= \underline{\underline{975.36\,\mu m}}$

#2

$A_{before} = a\cdot b$

$A_{after} = (a+\Delta a)(b+\Delta b)$

$= ab + a\Delta b + \Delta a b + \cancel{\Delta a\Delta b}^{\to 0}$

$= ab + a(b\alpha\Delta T) + (a\alpha\Delta T)b$

$= ab + ab\,\alpha\Delta T + ab\alpha\Delta T$

$= ab + 2\,ab\,\alpha\Delta T$

$= A_{before} + 2A_{before}\alpha\Delta T$

$\underline{\underline{= A + A(2\alpha)\Delta T}}$

#3 Simple pendulum : $\omega = \sqrt{\frac{g}{L}}$ (You should be able to prove this.)

$\therefore P_{20°c} = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{L}{g}} = \frac{2\pi}{\sqrt{g}}\sqrt{L}$

$P_{0°c} = 2\pi\sqrt{\frac{L+L\alpha\Delta T}{g}}$ $\left(\begin{array}{l}\alpha_{brass} = 19\times10^{-6}/°c \\ \Delta T = 0°C-20°C = -20°c\end{array}\right)$

$= 2\pi\sqrt{\frac{0.99962L}{g}} = \frac{2\pi}{\sqrt{g}}\sqrt{0.99962L}$

$\frac{P_{0°c}}{P_{20°c}} = \frac{\frac{2\pi}{g}\sqrt{0.99962L}}{\frac{2\pi}{g}\sqrt{L}} = \sqrt{0.99962} = 0.99980998$1

$\Delta T/_{hr} = \frac{3600\,sec - 3600\,sec\,(0.999809981)}{hr} = \underline{\underline{0.684065\,sec/_{hr}\text{ faster}}}$

#4 $Q = 50.2\ kJ\ (50200 J)$

$L_F = 333\ kJ/kg = 333\ J/g$

$50200\ J \div 333\ J/g = 150.75\ g$ of $0°C$ of ice can be melted to $150.75\ g$ of $0°C$ of water.

$\therefore\ 260\ g - 150.75\ g = \underline{\underline{109.2492493\ g \text{ of ice is left}}}$

#5 $4000\ cal/day = 4 \times 10^6\ cal/day = 1.6744 \times 10^7\ J/day$ $(1\ cal = 4.186\ J)$

$P = \frac{W}{t} = \frac{1.6744 \times 10^7 J}{86400\ sec\ (= 1\ day)} = \underline{\underline{193.7962963\ Watts}}$

(~ 2 × 100 watt light bulbs)

#6 $mg\Delta h = 73\ kg\ (9.80\ m/sec^2)\ 8840\ m = 6.324136 \times 10^6 J$

$6.324136 \times 10^6 J \div (6000\ cal/g \cdot 4.186\ J/cal) = \underline{\underline{251.7971064\ g \text{ of butter}}}$

(~ 2 sticks of butter: No wonder we gain weight!)

#7 Every shake $\Rightarrow dQ = d(mg\Delta h)$

$Q_{needed} = m \cdot SHC \cdot \Delta T$

$= m \cdot 4190\ J/kg/°C \cdot (100°C - 15°C)$

$= 3.5615 \times 10^5\ m\ J/kg$

$\#\text{ shakes Needed} = \frac{Q_{needed}}{dQ} = \frac{3.5615 \times 10^5 \cancel{m}\ J/kg}{\cancel{m} \cdot 9.81 \cdot 0.3} = 121015.9701 \text{ shakes}$

$t = \frac{\#\text{ shakes needed}}{30\ shakes/min} \cdot \frac{1\ hr}{60\ min} \cdot \frac{1\ day}{24\ hrs} = \underline{\underline{2.801295604\ days}}$

(Good Luck!)

#8 $200 L$ of $H_2O = 200{,}000 g$ of H_2O

$\left[\ 1 L = 1000\ mL = 1000\ cm^3 = 1000\ g \text{ since } \rho_{H_2O} = 1\ g/cm^3 \right]$

Also

$700\ W/m^2 \times 0.2 = 140\ \frac{J/sec}{m^2} \Rightarrow 140\ \frac{J/sec}{m^2} \cdot \frac{60\ sec}{1\ min} \cdot \frac{60\ min}{1\ hr} = 50400\ \frac{J/hr}{m^2}$ — ①

Energy needed to raise 200 L of H_2O from 20°C to 40°C (in 1 hr)

SHC . mass . ΔT

$4.190\ J/g/°C \cdot 200000 \cdot (40°C - 20°C) = 1.676 \times 10^7 J$ — ②

② ÷ ①

$1.676 \times 10^7\ J/hr \div 50400\ \frac{J/hr}{m^2} = 33.25396825\ m^2$