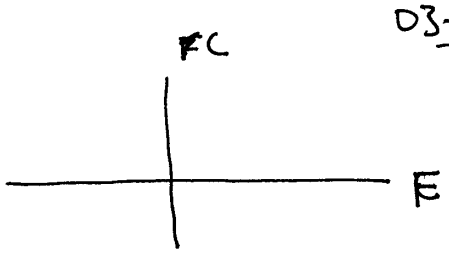
RJ S Schroeder

Prob 1.1

| | F° | C° |
|---|---|---|
| ice melts : | 32 | 0 |
| H2O Boils : | 212 | 100 |

pts (32,0) (212,100)




(a) Assuming a linear relationship between the two

$$F - 32 = \frac{(212-32)}{100-0}(C-0) = \frac{9}{5}C$$

$$F = \frac{9}{5}C + 32 \qquad \text{Check} \quad F(100) = 212 \quad \checkmark.$$

(b) $F(-273.15) = -459.67\ ^\circ F$.

Prob 1.2

$$R(F) = F - q \quad \rightarrow \quad R(-459.67) = -459.67 - q = 0$$

$$= q = +459.67$$

$$R(F) = F + 459.67 \qquad \underline{\underline{R = F + 459.67}}$$

$$R = \frac{9}{5}C + 32 + 459.67 \qquad C = k - 273.15$$

$$R = \frac{9}{5}(k - 273.15) + 32 + 459.67$$

$$= \frac{9}{5}k \qquad \underline{\underline{R = \frac{9}{5}k}}$$

Room temp $\approx 20^\circ C = \cancel{293\,K} \approx 300^\circ K. = 540^\circ R$

**Prob 1.3**

(a) $\approx 100^\circ F \Rightarrow \frac{5}{9}(100-32) \approx 38^\circ C. \cong 305^\circ K.$

(b) $100^\circ C \Rightarrow 373.15\ K.$

(c) $50^\circ F \Rightarrow 10^\circ C \Rightarrow 293.15\ K$

(d) $-196^\circ C \Rightarrow 77\ K$

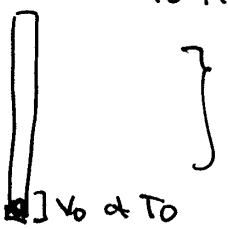
(e) $327^\circ C \Rightarrow \approx 600\ K$

**Prob 1.4** Density would be twice as great at a temperature.

**Prob 1.5** $\approx 2$ min.

**Prob 1.6** Physiological exp w/ ~~intertwined~~ intertwined hot & cold tops.
See an intro psycology book

**Prob 1.7** (a) Size of bulb $\approx 3$ mm $\approx$ maybe $\frac{1}{2}$ cm would be a better estimate.
$\Rightarrow V = \frac{4}{3}\pi(1.5\text{ mm})^3 = 14.13\ \text{mm}^3$
diameter tube $\approx 1$mm. (estimate)
to range from $0^\circ C$ to $100^\circ C \Rightarrow \Delta T = 100^\circ C = 100^\circ K$



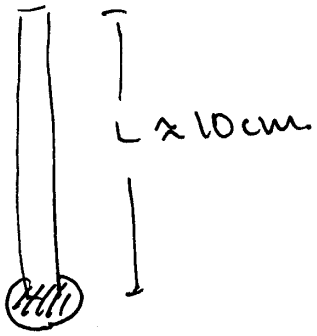
$V$ = size of initial bulb of Hg.

$$\beta = \frac{\Delta V/V}{\Delta T}$$

$$\Delta V = \frac{\beta V}{\Delta T} = \frac{(14.13\ \text{mm}^3)(1.81\cdot 10^{-4}\ \text{K}^{-1})}{100\ \text{K}}$$

$$= \beta V \Delta T = (1.81\cdot 10^{-4}\ \text{K}^{-1})(14.13\ \text{mm}^3)(100\ \text{K})$$

$$= 2.53\cdot 10^{-1}\ \text{mm}^3$$



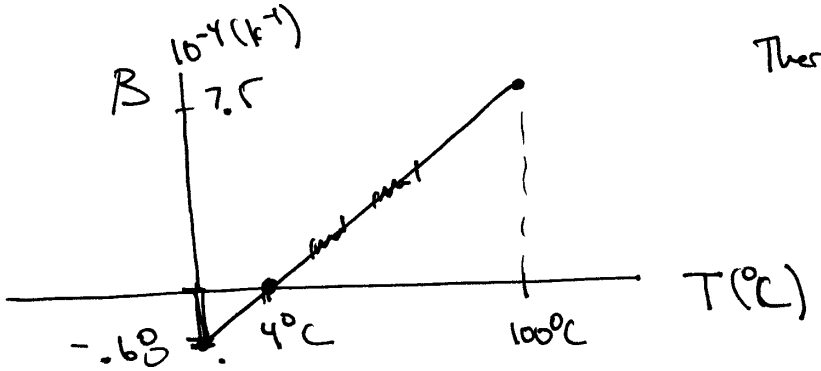

$$= L\pi r^2 \cong 31.4\ \text{cm}\ r^2$$

$$= 314\ \text{mm}\ r^2$$

$r^2 = 2.83\cdot 10^{-2}$ mm seems too small.

$\approx$ 3/100th of mm!!

(b)




Thermal expansion coeff of $H_2O$.

$\beta > 0 \Rightarrow$

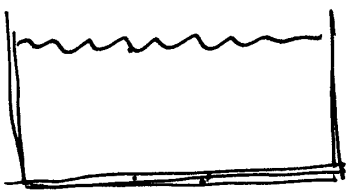
$$\beta \equiv \frac{\Delta V/V}{\Delta T}$$

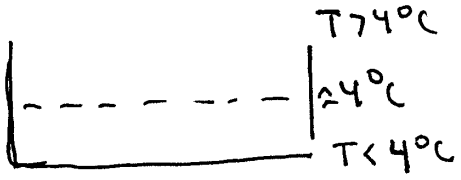
$\Delta V = \beta \Delta T V > 0$

$\Rightarrow \Delta T > 0$

or $\Delta V < 0 \Rightarrow \Delta T <$

$\beta < 0 \Rightarrow \Delta V > 0$ if



Think the answer is that if the thermal expansion was always positive ⇒ that lakes would freeze from the bottom up.

wouldn't we eventually have mixing?

Pb 1.8 $\quad \alpha \equiv \dfrac{\Delta L/L}{\Delta T}$

(a) $L = 1\,km \qquad 100°F = 310\,k$

$\Delta T = 16.8\,k \qquad 20°C = 293.15\,k$

$0°C = 273.15\,k$

$$\Delta L_{Hot} = \alpha L \Delta T = (1.1\cdot10^{-5}\,k^{-1})(1\,km)(16.8\,k) = 1.85\cdot10^{-4}\,km$$

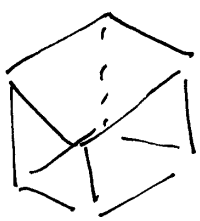
$$\Delta L_{cold} = \alpha L \Delta T = (1.1\cdot10^{-5}\,k^{-1})(1\,km)(-20\,k) \approx -1.85\cdot10^{-4}\,km$$

$=$

$$\Delta L_{total} = 2(.18\,m) = .36\,m$$

(b) Each metal has a different coefficient of thermal expansion. when sandwiched together as the temp changes the unit Bends

(c)



$\beta \equiv \dfrac{\Delta V/V}{\Delta T} \qquad V = L_x L_y L_z$

$\Delta V = \Delta L_x L_y L_z +$

$\Delta V =$ $\qquad L_x \Delta L_y L_z +$

$L_x L_y \Delta L_z$

$$\text{Thus } \frac{\Delta V}{V} = \frac{\Delta L_x}{L_x} + \frac{\Delta L_y}{L_y} + \frac{\Delta L_z}{L_z} = \Delta T \beta_x^{\alpha_x} + \Delta T \beta_y^{\alpha_y} + \Delta T \beta_z^{\alpha_z}$$

$$\Rightarrow \quad \alpha_x = \alpha_y = \alpha_z$$

$$3\alpha = \frac{\Delta V/V}{\Delta T} \equiv \beta$$

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$$nR = \frac{N}{N_A} R = N\left(\frac{R}{N_A}\right) = Nk$$

$$N = nN_A \Rightarrow n = \frac{N}{N_A}$$

**Problem 1.9** $n = 1$, $T = 20°C = 300\ k$, $P = 1\ atm = 1.01 \cdot 10^5\ Pa$

$$PV = nRT$$

$$V = \frac{nRT}{P} = \frac{(1\ mol)(8.314\ J/mol \cdot k)(300k)}{1.01 \cdot 10^5\ Pa} = 2.46 \cdot 10^{-2}\ J/Pa$$

$$= 2.46 \cdot 10^{-2}\ \frac{N \cdot m}{N/m^2} = 2.46 \cdot 10^{-2}\ m^3$$

**Prob 1.10** $PV = kNT$ $P = 1\ atm = 1.01 \cdot 10^5\ Pa$ $T = 300k$

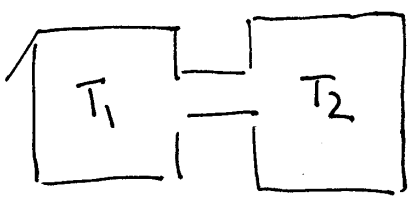
$k = 1.381 \cdot 10^{-23}\ J/k$

$V = (20\ m)^3 = 8000\ m^3$

$$N = \frac{(1.01 \cdot 10^5\ Pa)(8000\ m^3)}{(1.381 \cdot 10^{-23}\ J/k)(300\ k)}$$

$= 1.95 \cdot 10^{29}$ !! $=$ ~~300,000~~ 300,000 . moles !!

**Prob 1.11**




$T_2 > T_1$ Both of volum V.

$P_1V_1 = kN_1T_1$

$P_2V_2 = kN_2T_2$

Since $P_1 = P_2$ & $V_1 = V_2$

$N_1T_1 = N_2T_2$ Since $T_2 > T_1$, $N_2 < N_1$

Prob 1.12 $PV = NkT$ $\quad P = 1\ \text{atm} = 1.01 \cdot 10^5\ \text{Pa}$

$$P\left(\frac{V}{N}\right) = kT$$

$$\frac{V}{N} = \bar{v} = \frac{kT}{P} = \frac{(1.38 \cdot 10^{-23}\ \text{J/k})(300\ \text{k})}{1.01 \cdot 10^5\ \text{Pa}} = 4.099 \cdot 10^{-26}\ \text{m}$$

$$\bar{\ell} = \sqrt[3]{\bar{v}} = 3.44 \cdot 10^{-9}\ \text{m} = 3.44\ \text{nm}$$

Sits of $N_2 \sim 10^{-10}$ so yes.

Prob 1.13 $N_A \cong N_{\text{protons/gm}}$

$m_N \cong m_P$

$m_e \ll m_N$

atomic mass $\approx$ # protons & neutrons.

mass in grams of one mole of a substance

To approx required atomic mass $\approx$ total # of protons + neutrons

$H_2O = 2(2) + 1(8) = 12$ gms/mole.

$2(1.) + 1(16) = 18$ gm/mole

$N_2 = 2(14) = 28$ gm/mole

lead = Pb = 207 gm/mole

$SiO_2 = 28.08 + 2(16) = 60$ gm/mole

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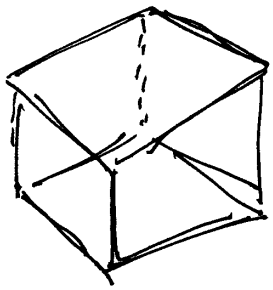
Prob 1.14 $P = 1\ atm$



$nR = Nk$

$M_{Air} = \cancel{F_{O_2} m_{O_2} + \dots}$

$= N_{O_2} m_{O_2} + N_{N_2} m_{N_2} + N_{Ag} m_{Ag}$

consider 1 mole of Air

$PV = nRT$

$V = \frac{RT}{P} = \frac{N_A k T}{P}$ what are $N_{O_2}, N_{N_2}, N_{Ag}$ ?

$N_A = N_{O_2} + N_{N_2} + N_{Ag}$

Daltons law of partial pressure

$P = P_1 + P_2 + P_3 = \frac{N_{N_2} kT}{V} + N$

$\|$

$\frac{N_A kT}{V}$

Assuming that volume percentage is the same as molecule percentage:

How do I show this?

$N_{N_2} = .78(N_A) =$

$N_{O_2} = .21 N_A$

$N_{Ag} = .01 N_A$

$\rightarrow M_{Air} = (.78 m_{N_2} + .21 m_{O_2} + .01 m_{Ag}) N_A$

~~$M_{Air} = (.78(28) + .21(16) + .01(39.9))(6.02 \cdot 10^{23})$~~

$M_{\bar{U}}$ = Mass per molecule = $\bar{M}_{\bar{U}}$

$$\bar{M} = \frac{\#\text{ grams}}{\text{mole}} \cdot \frac{1\text{ mole}}{N_A\text{ atoms}} = \frac{1}{N_A}\frac{\#\text{ grams}}{\text{atom.}} = \frac{1}{N_A} m_{\bar{U}}$$

Thus $$M_{Air} = \left(.78\frac{M_{N_2}}{N_A} + .21\frac{M_{O_2}}{N_A} + .01\frac{M_{Ag}}{N_A}\right)N_A$$

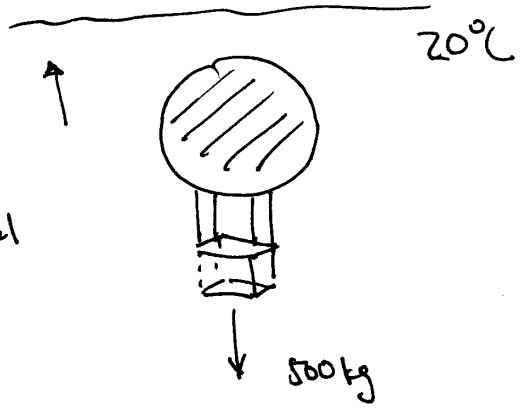
$$= (.78 M_{N_2} + .21 M_{O_2} + .01 M_{Ag}) =$$

$$= .78(28) + .21(16) + .01(39.9) = 25.59 \text{ grams/mole.}$$

Prob 1.15

Boyancy force = $g V \rho_{Air\ displaced}$

$\rho_{Air}$ = mass density of air around balloon. or normal air. [grams/$m^3$]




$PV = nRT$ $\quad n = \frac{M}{m}$ $\quad \frac{\text{total mass}}{\text{mass per unit mole}}$

$$= \frac{M}{m}RT$$

$$\rho^{-1} = \frac{V}{M} = \frac{RT}{mP} \quad \text{or} \quad \rho^{-1}_{Air} = \frac{RT}{mP} \approx \frac{(8.314\ J/mol\cdot k)(300\ ^\circ k)}{(25.59\cdot 10^{-3}\ kg/mol)(1.01\cdot 10^{5}\ Pa)}$$

$$= \qquad = 9.65 \cdot 10^{-1}\ \frac{J}{kg \cdot Pa}$$

$$\frac{J}{kg \cdot Pa} = \frac{N \cdot m}{kg \cdot \frac{N}{m^2}} = \frac{m^3}{kg} \Rightarrow$$

$$\Rightarrow \rho = 1.01 \ kg/m^3$$

Thus so that Boyancy force exactly balances wght

$$\rho V \rho_{Air} = (500 kg) g$$

$$V = \frac{500 \ kg}{1.01 \ kg/m^3} = 495 \ m^3$$ is the volume of the air inside the ballon.

I was trying to get an estimate of the volume of the ballon + hoping to then get an estimate of the temperature.

Guessing the temp in the ballon is $30°C = 310 K$.

$$PV = nRT \Rightarrow n_{Air} = \frac{(1.01 \cdot 10^5 Pa)(495 \ m^3)}{(8.314 \ J/mol \cdot K)(310 \ K)}$$

$$= 19397 \text{ moles}$$

$$Mass = n_{Air}(25.59 \ grams/mol) = 496 \ kg \ Air.$$

from prob 1.14

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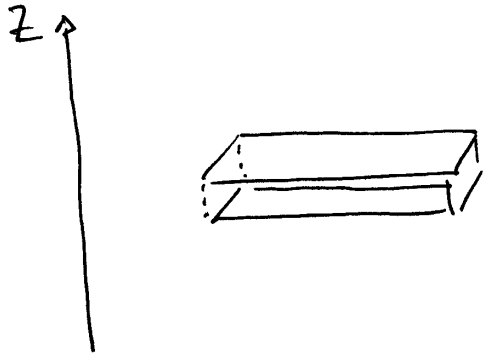
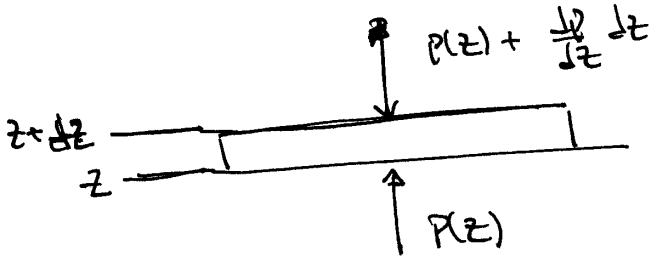
Prob 1.16




$\therefore$ ~~$P(z) \mp \frac{dP}{dz} dz$ $P(z)$ force~~

$$A\left(P(z) - P(z) - \frac{dP}{dz} dz\right) = \text{Force up} = \rho g A\, dz$$

(a) $$\frac{dP}{dz} = -\rho g$$ $\rho$ = Mass density.

$$PV = nRT = \frac{M}{m} RT \Rightarrow \frac{M}{V} = \frac{PM}{RT} \Rightarrow \rho = \frac{PM}{RT}$$

$$\Rightarrow \frac{dP}{dz} = -g\left(\frac{PM}{RT}\right) = -\frac{Mg}{RT} P$$ Same result obtained in Ch 7.

$m$ = mass per unit mole. $nR = k_B N$

$n = \frac{M}{m}$ $\frac{M}{m} R = kN =$ ~~k~~

03-10-02

$R = \frac{mkN}{M} = mk\left(\frac{N}{M}\right) = \frac{mk}{m_0}$ $\quad m_0$ = mass per molecule

~~$PV = nRT$~~ $\quad m$ = Avg mass of air molecules per mole.

(c) Th $P(z) = P_0 e^{-\frac{mg}{RT}z}$ $\quad PV = \frac{M}{m}RT$

$\therefore P = \frac{mP_0}{RT} e^{-\frac{mg}{RT}z}$. $\quad \rho = \frac{m}{V} = \frac{mP}{RT}$

$m = 25$ g/mol

(d) $P(z) = (1\text{atm}) \exp\left\{-\frac{(25\ \text{g/mol})(9.8\ \text{m/s}^2)}{(8.314\ \text{J/mol·k})(300\ \text{k})} z\right\}$

coefficient $= \frac{(25 \cdot 10^{-3})(9.8)}{8.314 \cdot 300}$ $\frac{\text{kg m/s}^2}{\text{J}} = \frac{\text{kg m/s}^2}{\text{kg} \cdot \text{m}^2/\text{s}^2} = \frac{1}{m}$

$= 2.94 \cdot 10^{-2}\ \text{m}^{-1} = 9.822 \cdot 10^{-5}\ \text{m}^{-1}$

$\therefore P(z) = 1\text{atm} \exp\left\{-\frac{z}{33.9\text{m}}\right\}$

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Prob 1.17

(a) $\frac{V}{n} = \frac{(8.314\ J/mol\,K)\,T}{1.01\cdot10^5\ Pa}$

$1\,cm^3 = 1\,(10^{-2}\,m)^3$

$= 10^{-6}\,m$

see table 1.2.

The ~~fff~~ 2nd viral coeff is

$$\frac{B(T)}{\left(\frac{R}{P}T\right)} = \cdots$$

All terms are smaller than 1/100.

(b) $B(T) < 0$ T small $\Rightarrow$ PV smaller than predicted by Ideal gas law.

$\Rightarrow$ ~~atoms~~ atoms may attract?

~~B~~ $B(T) > 0$ T large atoms may repl?

(c) $\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$

$$PV\left(1 + \frac{an^2}{PV^2}\right)\left(1 - \frac{nb}{V}\right) = nRT$$

$$PV = \frac{nRT}{\left(1 + \frac{an^2}{PV^2}\right)\left(1 - \frac{nb}{V}\right)} = \frac{nRT}{\left(1 - \frac{a}{PV^2}\right)\left(1 - \frac{b}{V}\right)}$$

$$= \frac{nRT}{\left(1 - \frac{a}{P}x^2\right)(1 - bx)} = nRT\left(1 + \frac{b}{V} + \left(b^2 + \frac{a}{P}\right)\frac{1}{V^2} + \cdots\right)$$

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... virial given

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$$

$$P(V - nb) + \frac{an^2}{V^2}(V - nb) = nRT$$

$$PV\left(1 - \frac{nb}{V}\right) = nRT + -\frac{a}{\bar{V}^2}(V - nb)$$

$$PV = \frac{nRT - \frac{a}{\bar{V}^2}(\bar{V} - b)n}{\left(1 - \frac{nb}{V}\right)}$$

$$PV = nRT\left(\frac{1 - \frac{a}{\bar{V}^2}(\bar{V} - b)\frac{1}{RT}}{\left(1 - \frac{b}{\bar{V}}\right)}\right)$$

$$\therefore PV \cong nRT\left(1 - \frac{a}{RT}\left(\frac{1}{\bar{V}} - \frac{b}{\bar{V}^2}\right)\right)\left(1 + \frac{b}{\bar{V}} + O\left(\frac{1}{\bar{V}^2}\right)\right)$$

$$= nRT\left(1 - \underline{\frac{a}{RT}\frac{1}{\bar{V}}} + \underline{\underline{\frac{a}{RT}\frac{b}{\bar{V}^2}}} + \underline{\frac{b}{\bar{V}}} - \underline{\underline{\frac{ab}{RT}\left(\frac{1}{\bar{V}}\right)^2}} + \frac{ab^2}{RT}\left(\frac{1}{\bar{V}}\right)^3 + \cdots\right)$$

$$PV = nRT\left(1 - \left(\frac{a}{RT} - b\right)\frac{1}{\bar{V}} + \left(\frac{ab}{RT} - \frac{ab}{RT}\right)\frac{1}{\bar{V}^2} + O\left(\frac{1}{\bar{V}^3}\right)\right)$$

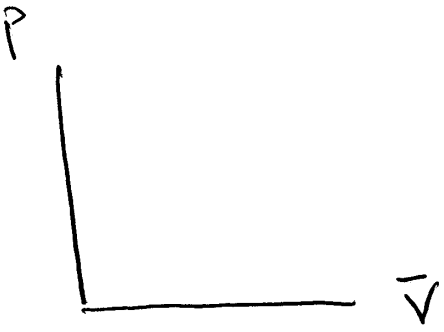
$$\therefore \quad B(T) = b - \frac{a}{RT} \qquad C(T) = 0$$

(d) w/

$$B(T) = b - \frac{a}{RT}$$

Calculate b & a from data given, then plot.

$$\left(P + \frac{a}{\bar{V}^2}\right)(\bar{V} - b) = RT$$




ie. Solve for P given $\bar{V}$

$$\left(P(V) + \frac{a}{\bar{V}^2}\right)$$

$$P(V) = \frac{RT}{\bar{V} - b} - \frac{a}{\bar{V}^2}$$

From the data given in the text we get that

$$B(T) \cong .0000642 - \frac{.02192}{T} \overset{\text{set}}{=} b - \frac{a}{RT}$$

$\Rightarrow b = 6.42 \cdot 10^{-5}$ $\quad a = .02192(8.314) = .18207$

$$\bar{P} = \frac{\bar{F}_x}{A} = -\frac{\bar{F}_{x,m}}{A} = -\frac{m\frac{\Delta v_x}{\Delta t}}{A}$$

$$\Delta t = \frac{2L}{v_x}$$

$$\Delta v_x = v_{x,\text{final}} - v_{x,\text{initial}} = -v_x - v_x = -2v_x$$

$$\bar{P} = \frac{-m(-2v_x)}{\frac{\frac{2L}{v_x}}{A}} = \frac{\frac{mv_x^2}{L}}{A} = \frac{mv_x^2}{LA} = \frac{mv_x^2}{V} \quad \text{eq 1.12}$$

$$PV = mv_{1x}^2 + mv_{2x}^2 + \cdots$$

$$= Nm\overline{v_x^2}$$

$$\| \quad NkT$$

$$kT = mv_x^2$$

$$\bar{k}_{\text{trans}} = \frac{3}{2}kT \qquad [k] = J/K$$

$$T_{\text{room}} \cong 300K$$

$$kT = 300K\,(1.38\cdot10^{-23}\,J/K) = 4.14\cdot10^{-21}\,J$$

$$1eV = 1.6\cdot10^{-19}\,J$$

Th

$k_B = 1.38 \cdot 10^{-23} \text{ J/K} = 1.38 \cdot 10^{-23} \left(1/1.6 \cdot 10^{+19}\right) \text{ eV/K}$

$= .862 \cdot 10^{-4} \text{ eV/K}$

$= 8.62 \cdot 10^{-5} \text{ eV/K}$

$k_B(T)_{\text{room}} = \left(8.62 \cdot 10^{-5} \text{ eV/K}\right)(300 \text{ K})$

$= 0.26 \cdot 10^{-1} \text{ eV} = \frac{1}{40} \text{ eV}$

$\overline{V^2} = \frac{3}{m} kT \qquad V_{rms} = \sqrt{\frac{3}{m} kT}$

$V_{rms} \gtrsim \bar{V}.$

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Prob 1.8 $m_{N_2} = ?$

$1\ mol = 6.022 \cdot 10^{23}$

1 Mole of N weighs 14.0067 J

$\therefore M_{N_2} = 2(14.00)\ g/mol$

$\Rightarrow m = 2(14.00)\frac{1}{mol} \cdot \frac{1\ mol}{6.022 \cdot 10^{23}} = 4.64 \cdot 10^{-23}\ grams$

$V_{rms} = \sqrt{\frac{3kT}{m}} = \left(\frac{3(4.14 \cdot 10^{-21} J)}{4.64 \cdot 10^{-23}\ grams}\right)^{1/2}$ $\quad J/kg = \frac{kg \cdot m^2/s^2}{kg}$

$= 516.8\ m/s.$ $\quad \{1m = 6.2 \cdot 10^{-4}\ mi\}$

$= 3.2 \cdot 10^{-1}\ mi/s \cdot \frac{3600\ s}{hr}$

$= 1153.\ mi/hr.$

$1\frac{m}{s} = 6.2 \cdot 10^{-4} \cdot 3600\ mi/hr = 2.2\ mi/hr.$

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Prob 1.19

$H_2 \Rightarrow m = 2(1.007)\ g/mol \cdot \frac{1}{6.022 \cdot 10^{23}} =$

$O_2 \Rightarrow m = 2(16)\ g/mol \cdot \frac{1}{6.022 \cdot 10^{23}} =$

$$v_{rms} = \sqrt{\bar{v}^2} = \sqrt{\frac{3k_B T}{m}}$$

$$\therefore v_{rms\,H_2} = \sqrt{\frac{3k_B T}{m_{H_2}}}$$

$$v_{rms\,O_2} = \sqrt{\frac{3k_B T}{m_{O_2}}}$$

intuitively, the smaller the mass the faster they should be travelling

$$\Rightarrow \frac{v_{rms\,H_2}}{v_{rms\,O_2}} = \sqrt{\frac{m_{O_2}}{m_{H_2}}} = \sqrt{\frac{2(16)}{2(1.007)}}$$

$$\Rightarrow \frac{v_{rms\,H_2}}{v_{rms\,O_2}} = \sqrt{\frac{16}{1.007}} =$$

Prb 1.20

$$m_{U^{238}F_6} = \frac{(6(19) + 238)}{6.022 \cdot 10^{23}} \text{ g/mol} = 5.845 \cdot 10^{-22} \text{ g}$$

$$m_{U^{235}F_6} = \frac{(6(19) + 235)}{6.022 \cdot 10^{23}} \text{ g/molec} = 5.795 \cdot 10^{-22} \text{ g}$$

$$v_{rms\,U^{238}F_6} = \sqrt{\frac{3k_BT}{m_{U^{238}F_6}}} = \sqrt{\frac{3(4.14 \cdot 10^{-21} \cdot 10^3 \text{ g m}^2/\text{s}^2)}{5.845 \cdot 10^{-22} \text{ g}}}$$

$$= 148.7 \text{ m/s}$$

$$v_{rms\,U^{235}F_6} = \sqrt{\frac{3(4.14 \cdot 10^{-21} \cdot 10^3 \text{ g m}^2/\text{s}^2)}{5.795 \cdot 10^{-22} \text{ g}}} = 146.3 \text{ m/s}$$

About 1 m/s difference in speed

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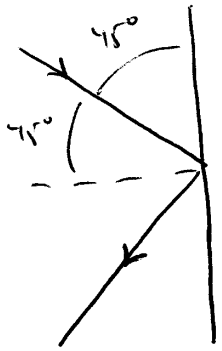
07-10-02 1

Prob 1.21

$m = 2\,g \quad V = 15\ m/s$

$f = 30\ 1/s$




$\bar{P}_{pressure} = \frac{\bar{F}}{A} =$

$\bar{F} = \frac{\overline{\Delta p}}{\Delta t}$ w/ $\Delta p$ = change in momentum.
$\Delta t$ = interval of time over which this change happens

$= \frac{p_{x,final} - p_{x,initial}}{\Delta t} = \frac{(-V_0 \cos 45° - V_0 \cos 45°)m}{\Delta t}$

$= \frac{(-2V_0 \cos 45°)m}{\Delta t} = -\frac{2V_0}{\sqrt{2}} \frac{m}{\Delta t}$

Now $\Delta t$ = Avg time between collisions $= \frac{1}{f} = 30^{-1}\,s$

$\therefore \bar{F} = -\frac{2(15\ m/s)(2g)}{\sqrt{2}\,(30^{-1}\,s)} = 1272.7\ g\,m/s^2$

$= 1.27\ kg\,m/s^2 = 1.27\ N$

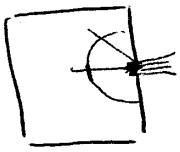
$\therefore \bar{P} = \frac{1.27}{.5}\ Pa = 2.54\ Pa$

~~KPa = 40 atm.~~ $1\ atm = 1.013 \cdot 10^5\ N/m^2 \Rightarrow \bar{P} = 2.5 \cdot 10^{-5}\ atms.$

Seems very small.

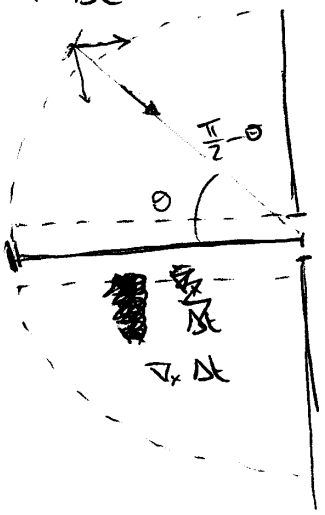
# Pg 14 Schroeder

Prob 1.22



(a)

in $\Delta t$ # molecules colliding is coming from a distance $\left(\frac{\Delta t}{\bar{v}_x}\right)^{-1}$ away or nearer




Assume all molecules in the ½ sphere centered at the effusion hole go thru the hole

$$\frac{1}{3}\frac{\bar{v}_x}{\Delta t}\left(\frac{1}{2}\left(\frac{4}{3}\pi(\bar{v}_x\Delta t)^3\right)\right) = \bar{v}_0.$$

# of molecules in this vol. is

$$PV = NkT$$

---

Assume the pressure of this point comes from only molecular inputs.

Then $$\bar{P} = \frac{\bar{F}}{A} = \frac{1}{A}\left(\frac{\Delta p}{\Delta t}\right) = \frac{1}{A}\frac{(+2\bar{v}_x)m}{\Delta t}\cdot N$$

$$\Rightarrow N = \frac{AP\Delta t}{2\bar{v}_x m}$$

(b) This follow directly from 1.15 $\quad m\bar{v}_x^2 = kT$

$$\Rightarrow \bar{v}_x^2 = \sqrt{\frac{kT}{m}}$$

(c) Now the difficulty is that $P = P(V) = P(N)$ & $\Delta t$ for an infinitesimal time interval

$$\frac{AP\,dt}{2\bar{v}_x m} = \frac{AP}{2m}\,dt\sqrt{\frac{m}{kT}}$$ of $N$ is lost put negative sign

$$\Rightarrow \quad dN = -\frac{AP}{2m}\sqrt{\frac{m}{kT}}\,dt$$

$$\frac{dN}{dt} = \frac{-A\sqrt{m}}{2m}\left(\frac{kNT}{V}\right)\sqrt{kT}$$

$\{P = \frac{kNT}{V}\}$ $\{PV = NkT\}$

$$\Rightarrow \frac{dN}{dt} = \frac{-A}{2\sqrt{m}}\frac{\sqrt{kT}}{V}N \quad \checkmark \text{ integrating th}$$

$$\frac{dN}{N} = -\frac{A}{2V}\sqrt{\frac{kT}{m}}\,dt \equiv -\frac{1}{\tau}dt \qquad \text{w/ } \tau \equiv \frac{2V}{A}\sqrt{\frac{m}{kT}}$$

$$\ln N = \frac{t}{\tau} + C$$

$$N = N_0 e^{-t/\tau}$$

$[\tau] = L$

$[kT] = J$

$\left[\frac{m}{kT}\right] = \frac{M}{ML^2/T^2} = \frac{T^2}{L^2}$

$\therefore [\tau] = L\frac{T}{L} = T$ ✓

(d) $T = 300°$ room temp.

$V = 1 \text{ liter} = 10^{-3}\ m^3$

$A = 1 mm^2$

$m_{Air} = .7\,m_{N_2} + .3\,m_{O_2}$

$m_{N_2} = 2(14)\ g/mol \cdot \frac{1}{6.022\cdot10^{23}\ atms/mol} = 4.649\cdot10^{-23}\ g/atom$

$m_{O_2} = \frac{2(16)\ g/mol}{6.022\cdot10^{23}\ atms/mol} = 5.313\cdot10^{-23}\ g/molecule$

$\therefore m_{Air} \cong (.7(4.649) + .3(5.313))\cdot10^{-23}\ g/molecule$

$= 4.84\cdot10^{-23}\ g/molecule$

$$kT = (1.38\cdot10^{-23}\ J/k)(300k)$$

$$= 4.14\cdot10^{-21}\ J$$

$$\sqrt{\frac{m}{kT}} = \sqrt{\frac{4.84\cdot10^{-3}\cdot10^{-23}}{4.14\cdot10^{-21}}\ \frac{kg}{J}} = 3.42\cdot10^{-3}\quad \left(\frac{s}{m}\right)$$

$$\frac{A}{V} = \frac{1(10^{-3})^2\ m^2}{10^{-3}\ m^3} = \frac{10^{-3}}{m}$$

$$\tau = 2\cdot10^3\,(3.42\cdot10^{-3})\ s$$

$$\therefore\quad n(t) = N_0 e^{-t/6.84s}$$

(e) $e^{-1} = .367$

$e^{-2} = .135$

$e^{-3} = .05$ ← this is what I'm looking for

$t \doteq 1hr = 3600\ s.$ $\quad \tau =$

$$-\frac{t}{\tau} \doteq -3$$

$$\Rightarrow\quad t \doteq 3\tau = 3.2\frac{V}{A}\sqrt{\frac{m}{kT}} = 3.2\frac{V}{A}\left(3.42\cdot10^{-3}\ s/m\right)$$

$V \approx 1$ liter? How true.

$$\Rightarrow\quad 3600\ s = 3.2\frac{(10^{-3}\ m^3)(3.42\cdot10^{-3}\ s/m)}{A}$$

$\Rightarrow A = 5.7 \cdot 10^{-9}\ m^2$

$= 5.7 \cdot 10^{-9} (10^6)\ mm^2$

$= 5.7 \cdot 10^{-3}\ mm^2$ ... seem to small.

(7) know $v_{rms} \cong$ hundreds of meter / second.

It is likely that they could move that fast.

# PS 17 Schroeder

**Prob 1.23** $U_{thermal} = N \cdot f \cdot \frac{1}{2}kT$ $\quad f_{diatomic} = 5.$

$$N = \frac{PV}{k_B T}$$

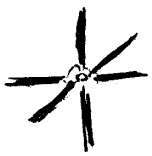
$$U_{thermal} = \left(\frac{PV}{k_B T}\right) f \left(\frac{1}{2} k_B T\right) = \frac{f}{2} PV.$$

$$U_{thermal} = \frac{5}{2}(1\ \text{atm})(1\ \text{liter}) = 2.5(10^5\ \text{Pa})(10^{-3}\ m^3)$$

$$= 2.5 \cdot 10^2\ \text{J} = 250\ \text{J}$$

$1\ \text{atm} = 10^5\ \text{Pa}$.

Calculation would be the same



**Prob 1.24** $U_{thermal} = N \cdot f \cdot \frac{1}{2}kT$ $\quad f_{solids} = 3(2)$

one for potential & one for ~~thermal~~ ~~energy~~ kinetic

$N = 1\ \text{gram}$

$1\ \text{mole} = 207.\ \text{g}$

$1\ \text{gram} = \frac{1}{207}\ \text{mole}$

$$\therefore N = \frac{6.022 \cdot 10^{23}}{207}\ \text{atoms} = 2.9 \cdot 10^{21}\ \text{atoms}$$

$$U_{th} = (2.9 \cdot 10^{21})(6)(.5)(1.38 \cdot 10^{-23}\ \text{J/K})(300\ \text{K}) = 36.1\ \text{J}$$

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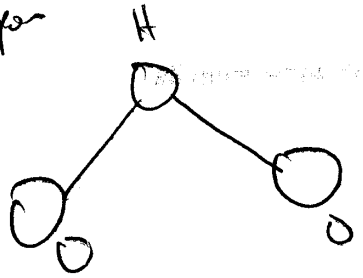
Prob 1.25 $H_2O$ vapor




3 degrees for translational.
3 degrees for rotational.
2 degrees ∀ except bond
1 degree for ∃ spring motion ~~Bad~~ in ring of molecule.

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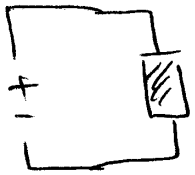
**Prob 1.26**



Classify it as work since it would not happen spontaneously.

If one is moving electrons along from the resistor to the $H_2O$ is heat since this is happening spontaneously.

**Prob 1.27** Pumping a bicycle tire melting an ice cube, or any process where work is generated as a by product of the heat added.

**Prob 1.28** $T_i = 300°k$ $T_f = 100 + 273 = 373°k$.

600 watt microwave

$$\frac{\Delta U}{\Delta t} = 600 J/s \rightarrow \Delta U = 600\ J/s\ \Delta t$$

Assuming the fluid ($H_2O$) does no volume work.

$U_{thermal} = N f \frac{1}{2} kT$

$\Delta U = (Nf \frac{1}{2} k)\ \Delta T$ know $\Delta T = 73°k$

$$(600\ J/s\ \Delta t) = (N 7 \tfrac{1}{2} k)\ \Delta T$$

$7 = 3.$

$$\Delta t = \frac{N 7 \frac{1}{2} k\ \Delta T}{600\ J/s}$$

$N =$

$M = 2(1) + 16 = 18\ g/mol$

$1\ cut \hat{=} 50$ grams. (more like 200 grams)

$$\Rightarrow N = \left(\frac{50\ gram}{18\ g/mol}\ 6.022 \cdot 10^{23}\right) = 1.67 \cdot 10^{24}\ molecules$$

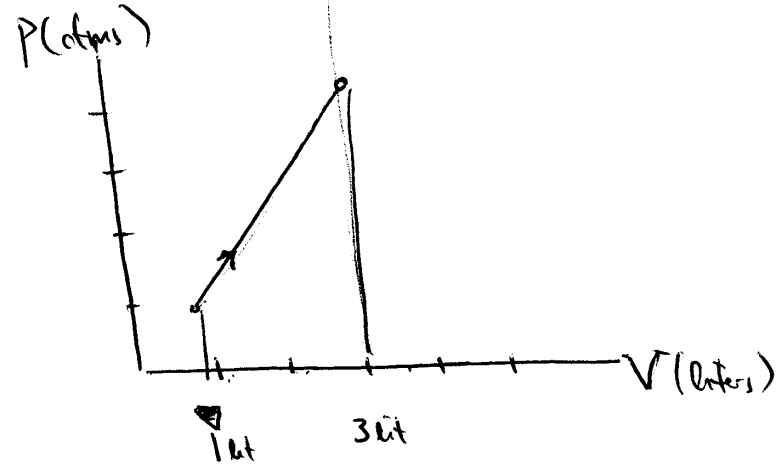
$\Delta t = 4.2\ s$ . Test!!

Prob 1.29 Nothing. The increase in temperature indicates that energy has flown into the $H_2O$. But this energy could have come from 1) heat or 2) work.

Prob 1.30 ?

Prob 1.31 $P = \alpha V$

(a)




(b) $W = -\int_{V_i}^{V_f} P\,dV$

$= -\frac{\alpha}{2}(V_f^2 - V_i^2) = -\frac{\alpha}{2}(9-1) = -4\alpha$

$T = \frac{PV}{kN}$

(d) $\Delta U = Q + W$.

$\therefore$

$Q = \Delta U - W$

$= \frac{\alpha f}{2}(V_f^2 - V_i^2)$

$+ \frac{\alpha}{2}(V_f^2 - V_i^2)$

$Q = \frac{\alpha}{2}(1+f)(V_f^2 - V_i^2)$

$= \frac{\alpha}{2}(4)(8) = 16\alpha$

(c) $\Delta U = N \cdot f \cdot \frac{1}{2} k \Delta T$.

$= Nf \frac{1}{2} k \Delta\left(\frac{PV}{kN}\right)$

$= \frac{f}{2}\Delta(V \alpha V)$

$= \frac{\alpha f}{2}\Delta(V^2)$

$= \frac{\alpha f}{2}(V_f^2 - V_i^2) =$

helium $f = 3$

$= \alpha\left(\frac{3}{2}\right)(8) = 12\alpha$

(e) Heat the container (or allow heat to flow).

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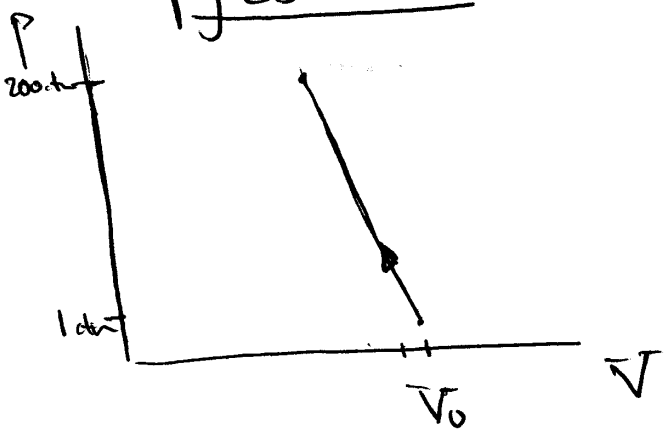
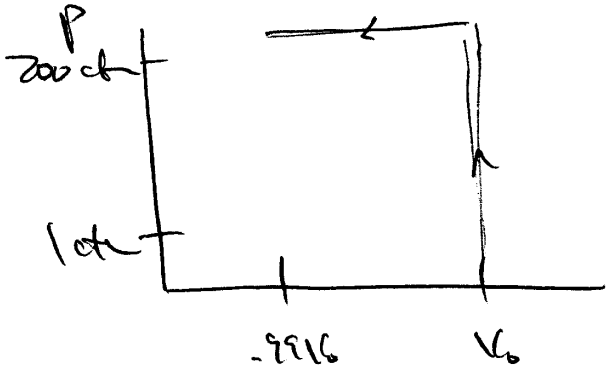
Prob 1.32




$$W = -\int_{V_i}^{V_f} P\,dV$$

Assume constant pressure when the system would look more like the following




$= -200\text{atm}(V_f - V_i)$

$= -200\text{atm}(.99V_i - V_i)$

$= 200(.01)\ \text{atm}\cdot m^3\,[V_i]$

$= 2\ \text{atm}\cdot m^3$ ?

Prob 1.33 (a) A: (a) ~~Negative~~ work done on gas

(b) ~~Yes~~. Don't think I can calculate this.

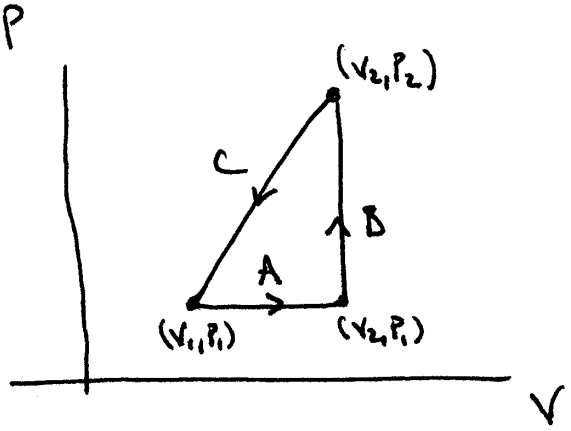
(c)

$U_{thermal} = N \cdot f \cdot \frac{1}{2}kT$

A:

(Prob 1.33) (a) Work done on gas is negative

$$W = -\int_{V_1}^{V_2} P_1\,dV = -P_1(V_2 - V_1) < 0$$




(b) $\Delta U = N \cdot f \frac{1}{2} k \Delta T$

4 #'s $V_1, V_2$
$P_1, P_2$.

$$T = \frac{PV}{Nk} \qquad \Delta T = \frac{1}{Nk}\Delta(PV)$$

$$\therefore \Delta U = N \cdot f \frac{1}{2} k \frac{1}{Nk} \Delta(PV) = \frac{f}{2}\Delta(PV) = \frac{f}{2} P_1(V_2 - V_1) > 0$$

(c) $\Delta U = W + Q$

$$\frac{f P_1}{2}(V_2 - V_1) = -P_1(V_2 - V_1) + Q \quad \therefore \quad Q = P_1(V_2 - V_1)\left\{\frac{f}{2} + 1\right\} > 0$$

B:

(a) $W = 0$ since $dV = 0$

(b) $\Delta U = \frac{f}{2}\Delta(PV) = \frac{f}{2} V_2(P_2 - P_1) > 0$

(c) $Q = \Delta U = \frac{f}{2} V_2(P_2 - P_1) > 0$

C: Along path C $P(V) = P_1 + \alpha(V - V_1)$ w/ $\alpha = \frac{P_2 - P_1}{V_2 - V_1}$

(a) $\therefore W = -\int_{V_2}^{V_1} P(V)\,dV = -P_1(V_1 - V_2) - \alpha \int_{V_2}^{V_1} (V - V_1)\,dV$

$$W = -P_1(V_1 - V_2) - \alpha \int_{V_2 - V_1}^{0} V\,dV$$

$$= -P_1(V_1 - V_2) - \frac{\alpha}{2}\left(0 - (V_2 - V_1)^2\right)$$

$$= -P_1(V_1 - V_2) + \frac{\alpha}{2}(V_2 - V_1)^2 = (V_2 - V_1)\left\{ +P_1 + \frac{1}{2}(P_2 - P_1)\right]$$

$$= (V_2 - V_1)\left\{ \frac{P_2}{2} + \frac{P_1}{2}\right\} = \frac{1}{2}(V_2 - V_1)(P_1 + P_2) > 0$$

(b) $\Delta U = \frac{f}{2}\Delta(PV) = \frac{f}{2}(P_1V_1 - P_2V_2) = \frac{3}{2} \overset{?}{<} 0$

(c) The $Q = \Delta U - W$

$$= \frac{f}{2}(P_1V_1 - P_2V_2) - \frac{1}{2}(V_2 - V_1)(P_1 + P_2)$$

$$= \frac{f}{2}(P_1V_1 - P_2V_2) -$$

Overall:

(a) work $= \frac{1}{2}(V_2 - V_1)(P_2 - P_1)$

check: $\overset{?}{=} W_A + W_B + W_C$

$$= -P_1(V_2 - V_1) + 0 + \frac{1}{2}(V_2 - V_1)(P_1 + P_2)$$

$$= (V_2 - V_1)\left\{ -P_1 + \frac{P_1}{2} + \frac{P_2}{2}\right] = (V_2 - V_1)\frac{1}{2}\left\{ P_2 - P_1\right] \quad \text{As above } \checkmark.$$

(b)

(b) since $\Delta U = 0$

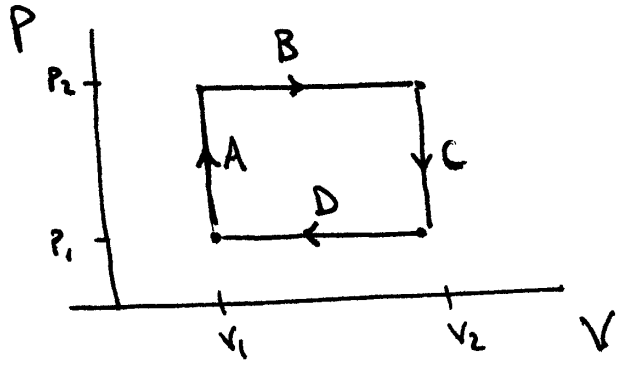
$$Q = -W = -(V_2 - V_1)\tfrac{1}{2}(P_2 - P_1) < 0$$

(c) $\Delta U = 0$

The process is a refrigerator.

Prob 1.34

(a)




A: $W = 0$

$$\Delta U = \tfrac{1}{2}\Delta(PV)$$

$$= \tfrac{1}{2}V_1(P_2 - P_1) > 0$$

$$Q = \tfrac{1}{2}V_1(P_2 - P_1) > 0$$

B: $W = -P_2(V_2 - V_1) < 0$

$$\Delta U = \tfrac{1}{2}P_2(V_2 - V_1) > 0$$

$$Q = \Delta U - W = \left(\tfrac{1}{2} + 1\right)P_2(V_2 - V_1) > 0$$

$\frac{1}{2} + 1 > 0$

$+1 > 2$ ✓.

C: $W = 0$

$$\Delta U = \tfrac{1}{2}V_2(P_1 - P_2) < 0$$

$$Q = \tfrac{1}{2}V_2(P_1 - P_2) < 0$$

D: $W = -P_1(V_1 - V_2) > 0$

$$\Delta U = \tfrac{1}{2}P_1(V_1 - V_2) < 0$$

$$Q = \tfrac{1}{2}P_1(V_1 - V_2) + P_1(V_1 - V_2) = \left(\tfrac{1}{2} + 1\right)P_1(V_1 - V_2) < 0$$

(b) A: Heat is added while the volume is kept fixed

B: Heat is still added this time allowing the volume to expand.

C: Heat is removed at constant volume.

D: I put work in while heat is still flowing at.

(c) $W = W_A + W_B + W_C + W_D$

$= 0 + -P_2(V_2 - V_1) + 0 + -P_1(V_1 - V_2)$

$= (V_2 - V_1)(P_1 - P_2) < 0$ I get work at.

$Q = \sum Q_i$

$= \frac{7}{2} V_1 (P_2 - P_1) + \left(\frac{7}{2} + 1\right) P_2 (V_2 - V_1)$

$+ \frac{7}{2} V_2 (P_1 - P_2) + \left(\frac{7}{2} + 1\right) P_1 (V_1 - V_2)$

$= \frac{7}{2} \left\{ V_1 P_2 - V_1 P_1 + P_2 V_2 - P_2 V_1 + V_2 P_1 - V_2 P_2 + P_1 V_1 - P_1 V_2 \right]$

$+ P_2 (V_2 - V_1) + P_1 (V_1 - V_2) = (V_2 - V_1)(P_2 - P_1) > 0$

~~$< (V_2 - V_1)(P_1 + P_2) < 0$~~

$\Delta U = 0.$

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Prob 1.35

$$VT^{f/2} = \text{const}$$

$$T = \frac{PV}{kN}$$

$$\propto V P^{f/2} V^{f/2} = \text{const}$$

$$P^{f/2} V^{\frac{2+f}{2}} = \text{const.}$$

$$PV^{\frac{2+f}{f}} = \text{const.}$$

$$\propto PV^{\gamma} = \text{const} \quad \text{w/} \quad \gamma = \frac{f+2}{f}$$

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07-11-02

**Prob 1.36**

$P_i = 1$ atm,

$P_f = 7$ atm.

(a) Adiabatic curves follow $PV^\gamma = \text{const.}$ $\gamma = \frac{f+2}{f}$

For diatomic air $f = 5$ $\gamma = \frac{7}{5} = 1.4$.

$$P_i V_i^\gamma = P_f V_f^\gamma$$

$$V_f = V_i \left(\frac{P_i}{P_f}\right)^{1/\gamma}$$

$$V_f = (1 \text{ liter}) \left(\frac{1 \text{ atm}}{7 \text{ atm}}\right)^{5/7} = .249 \text{ liters}.$$

(b) $$W = -\int_{V_i}^{V_f} P\,dV \qquad P = \underset{\text{Adiabatic}}{\frac{P_0}{V_0^\gamma} V^\gamma}$$

$$= -\frac{P_0}{V_0^\gamma} \int_{V_i}^{V_f} V^\gamma\,dV = -\frac{P_0}{V_0^\gamma} \left(\frac{V_f^{\gamma+1}}{\gamma+1} - \frac{V_i^{\gamma+1}}{\gamma+1}\right)$$

$$= -\frac{1 \text{ atm}}{(1 \text{ liter})^\gamma} \frac{1}{(\gamma+1)} \left((.249 \text{ liter})^{\gamma+1} - (1 \text{ liter})^{\gamma+1}\right)$$

$$= \frac{1 \text{ atm}}{(2.4)} \left(1 - (.249)^{2.4}\right) \text{ liter}.$$

$$= .401 \text{ atm} \cdot \text{liter}$$

$1 \text{ atm} = 10^5 \text{ Pa}$ $\quad 1 \text{ liter} = 10^{-3} \text{ m}^3$

$\therefore W = .401 \cdot 10^2 \text{ J}$

$= 40.1 \text{ J}.$

(c) $T_f = ?$ know $P_f$ & $V_f$ $\qquad P_i V_i = N k T_i$

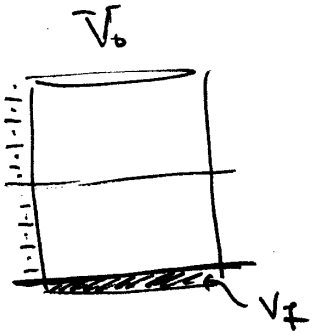
$P_f V_f = N k T_f$

$\Rightarrow$

$$\frac{P_i V_i}{P_f V_f} = \frac{T_i}{T_f} \qquad T_f = T_i \left( \frac{P_f V_f}{P_i V_i} \right)$$

$$\therefore T_f = 300\,k \left( \frac{7 \text{ atm} \cdot .249 \text{ liters}}{1 \text{ atm} \cdot 1 \text{ liter}} \right) = 522\,k.$$

Prob 1.37




Since compression is so fast process occurs adiabatically.

$T_i \cong 300K$ ; $V_i = V_0$ ; $P_i = 1 atm.$

$T_f = ?$ $\quad V_f = \frac{1}{20} V_0$

For an adiabatic process $\quad V T^{f/2} = V_i T_i^{f/2}$

Since Air is mostly diatomic $\Rightarrow \quad f = 3+2 = 5$

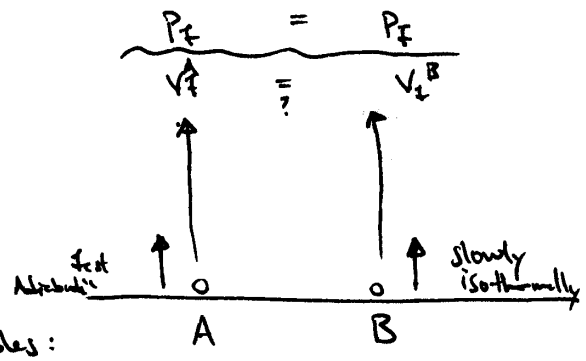
$$\frac{V_i}{20} T_f^{5/2} = V_i (300)^{5/2}$$

$$\Rightarrow T_f = 20^{2/5} (300) = 20^{2/5} (300) = 994\,K$$

this temperature must be above the flash point of ~~diesel~~ diesel fuel.

fuel.

Prob 1.38




$V_i^A, T_i^A, P_i^A = V_i^B, T_i^B, P_i^B$ initially, all variables are equal.

Bubble A undergoes an adiabatic transformation

$\Rightarrow P_f V_f^\gamma = P_i V_i^\gamma$ $\qquad V_{f\,\text{adiabatic}} = \left(\frac{P_i}{P_f}\right) V_i^\gamma$

Bubble B undergoes an isothermal transformation

$\Rightarrow P_f V_f = N k T = P_i V_i$

Thus $V_{f\,\text{isothermal}} = \left(\frac{P_i}{P_f}\right) V_i$

Thus is $V_{f\,\text{adiabatic}} \overset{?}{\gtrless} V_{f\,\text{isothermal}}$

$\Leftrightarrow V_i^\gamma \gtrless V_i$

$\Leftrightarrow V_i^{\gamma-1} \gtrless 1$

$\Leftrightarrow \gamma - 1 \gtrless 0 \quad \Leftrightarrow \quad \gamma \gtrless 1$

Since $\gamma > 1$ $\qquad \gamma = 1.4$ for a diatomic gas

then $V_{f\,\text{adiabatic}} > V_{f\,\text{isothermal}}$

Pg 27 Schroder

07-11-02

Prob 1.39

$$c_s = \sqrt{\frac{B}{\rho}}$$

$$B \equiv \frac{\Delta P}{\left(-\frac{\Delta V}{V}\right)} = -V\frac{\Delta P}{\Delta V} \qquad P = \frac{NkT}{V}$$

(a) $$B_{isothermal} = -\frac{V}{\Delta V}\Delta\left(\frac{NkT}{V}\right)$$

$$= -\frac{V}{\Delta V} NkT\left(\frac{-1}{V^2}\right)\Delta V = \frac{V}{V^2} NkT$$

$$= \frac{NkT}{V} = P$$

$$B_{adiabatic} = -\frac{V}{\Delta V}\Delta(P)$$

$$P = V^{-\gamma} P_i V_i^{\gamma} \qquad \Delta P = P_i V_i^{\gamma}(-\gamma) V^{-\gamma-1}\Delta V$$

$$\therefore B_{Adiabatic} = -V P_i V_i^{\gamma}(-\gamma) V^{-\gamma-1}$$

$$= \gamma P_i V_i^{\gamma} V^{-\gamma} = \gamma P$$

(b) Adiabatic process occur very quickly & compression of gas in a sound wave is this type of process.

(c) $$c_s = \sqrt{\frac{\gamma P}{\rho}} \qquad [\rho] = \frac{M}{V}.$$

$PV = NkT$ $\quad N = \frac{m}{M} \cdot N_A$.

$[m]$ = grams (mass of gas) $\quad M$ = Avg. molecular mass $\quad$ mass/mol

$[M]$ = grams/mole

$$\Rightarrow \quad PV = \frac{m}{M} N_A k T$$

$Nk = nR$

$\boxed{N_A k = R}$

$$\rho = \left(\frac{V}{m}\right)^{-1}$$

$$\therefore \quad P = \frac{\rho RT}{M}$$

{ why do I remember $P = \tilde{\rho} RT$ from gas dynamics? $\tilde{\rho}$ that is molar density not mass density

$$\therefore \quad c_s = \sqrt{\frac{\gamma RT}{M}}$$

{ if $[\tilde{\rho}] = \frac{\text{moles}}{\text{vol.}}$

$$\left[\tilde{\rho}\,\frac{1}{M}\right] = \frac{\text{mole}}{\text{vol}} \cdot \frac{1}{\text{grms/mole}} = \frac{\text{mol}}{\text{vol}}.$$

$$v_{rms} = \sqrt{\frac{3kT}{m}}$$

$$\left[\tilde{\rho} M\right] = \frac{\text{mole}}{\text{vol}} \cdot \frac{\text{g. mass}}{\text{mol}} = \rho_{mass} = \rho$$

$M = m N_A$

{ $P = \frac{\rho}{M}$

$\tilde{\rho} M = \rho$

$P = \tilde{\rho} RT$

$P = \frac{\rho}{M} RT$

So

$$c_s = \sqrt{\frac{\gamma RT}{m N_A}} = \sqrt{\frac{\gamma kT}{m}}$$

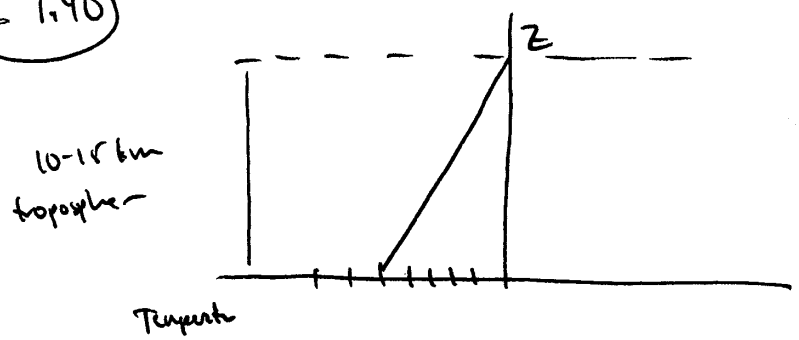
V.S. $\quad v_{rms} = \sqrt{\frac{\gamma kT}{m}}$

(c) $c_s^2 = \dfrac{1.4(8.314\ J/mol\cdot k)(300\ k)}{(.7(2)(14)+.3(2)(16))\ g/mol}$

$\Rightarrow c_s = \sqrt{\dfrac{3.49\cdot 10^3\ J}{29\cdot 10^{-3}\ kg}} = 345\ m/s.$

(d) At A higher altitude the Avg temperature is lower & thus I would expect the sound speed to decrease

Prob 1.40




(a) $PV^{\gamma} = \text{const.}$ + $VT^{f/2} = \text{const}$ $V =$

$$\frac{T^{\frac{f+2}{2}}}{P} = \text{const.}$$

$$\frac{f+2}{2} \ln T - \ln P = \text{const.}$$

$$\frac{f+2}{2} \frac{1}{T} dT - \frac{1}{P} dP = 0$$

$$\frac{dT}{dP} = \frac{2}{f+2} \frac{T}{P}$$

(b) $$\frac{dP}{dz} = \frac{-mg}{kT} P$$

$$\frac{dT}{dz} \cdot \frac{dz}{dP} = \frac{2}{f+2} \frac{T}{P}$$ Assum $\frac{dT}{dz} = \text{const.}$

$$\frac{dT}{dz} \cdot \left(\frac{-kT}{mg}\right) \frac{1}{P} = \frac{2}{f+2} \frac{T}{P}$$

$$\Rightarrow \frac{dT}{dz} = -\frac{mg}{k}\left(\frac{2}{f+2}\right)$$

$$m_{Air} = .7 m_{N_2} + .3 m_{O_2} = .7 \frac{2(14)}{6.022 \cdot 10^{23}} + .3 \frac{2(16)}{6.022 \cdot 10^{23}} = 4.84 \cdot 10^{-23} \text{ g/molecule}$$

~~$\frac{dT}{dz} = (4.84 \cdot 10^{-23})(9.$~~

~~$\frac{dT}{dt} = -(4.84 \cdot 10^{-23}\ J/\text{molecule})(980\ cm/s^2)$~~

$$\frac{dT}{dt} = -\frac{(4.84 \cdot 10^{-26}\ kg/\text{molecule})(9.8\ kg\,m/s^2)}{(1.38 \cdot 10^{-23}\ J/K)} \quad \frac{2}{(1.4+2)}$$

$$= 2.0 \cdot 10^{-2}\ \frac{K}{m}$$

$$= 2.0 \cdot 10^{-2}\ \frac{K}{10^{-3}\ km} = 20\ \frac{K}{km}. \quad \text{... mistake somewhere.}$$

**Prob 1.41**

(a) After significant time metal is at 100°C.

$\Delta U_{\text{heat content of metal}} = C\Delta T = C_{\text{metal}}(T_f - T_i)$

$\Delta U_{\text{metal}} + \Delta U_{H_2O} = 0$

$C_{\text{metal}}(24 - 100) + \left(\frac{250\,g}{18\,g}\right)(75.29\,J/k)(24-20) = 0$

$C_p(H_2O) = 75.29\ J/k$ per mole of substance.

1 mole $H_2O$ = 18 g.

∴ 75.29 J/k per 18 grams

$\Rightarrow$

(a) Heat gained by $H_2O$

$Q = 13.8(75.29\,J/k)(4) = 4.18 \cdot 10^3\ J. = 4183\ J.$

(b) Heat lost by metal = −4183 J

(c) $C_{\text{metal}} = \frac{-4183\,J}{-76\,k} = 55.03\ J/k$

(d) $c = \frac{C_{\text{metal}}}{100\,g} = .55\ J/g{\cdot}k.$

**Prob 1.42** $c = 1.8\ J/g\,C^\circ$

don't know the final temp of $H_2O$ & peeta mix. Might be lower than 100°C

$Q_{\text{Absorbed by Peeta}} = cm\Delta T = 1.8\,J/g\,C^\circ\,(340\,g)(100^\circ C - 25^\circ C)$

$= 45900\ J$

This amount of heat will be pulled from the $H_2O$

$$\Delta Q_{pasta} + \Delta Q_{H_2O} = 0$$

$$cm\Delta T + c_{H_2O} m_{H_2O} \Delta T = 0$$

$$(1.87 \text{ J/g°C})(340 \text{ g})(T_f - 25°C)$$

$$+ \left(\frac{75.29}{18} \frac{\text{J}}{\text{g·k}}\right)(10^3 \cdot 1.5 \text{ g})(T_f - 100°C) = 0$$

$$\Rightarrow \quad 612(T_f - 25) + 6.27 \cdot 10^3 (T_f - 100) = 0$$

$$6.88 \cdot 10^3 T_f = 6.42 \cdot 10^5$$

$$T_f = 93.27 \text{ °C} \quad \text{tops.}$$

$c_{H_2O} = 75.29$ J/mol·k

$c_{H_2O} = \frac{75.29}{18}$ J/g·k

1.5 liters =

1 liter $= 10^{-3}$ m$^3$.

1 cm$^3$ = 1 g for $H_2O$.

1 m = 100 cm

$\therefore$ 1 liter $= 10^{-3} \cdot (10^2)^3$ cm$^3$

$= 10^{-3} \cdot 10^6$ g

$= 10^3$ g

Prob 1.43 Ep $U_{thermal} = f \cdot N \cdot \frac{1}{2} k_B T$

$$C = \frac{U_{thermal}}{\Delta T}$$

From 1.46 $C_V = \left.\frac{\partial U}{\partial T}\right|_V = \frac{N \cdot f}{2}$

Th $\frac{C_V}{N} = \frac{f}{2}$

we know for liquid $H_2O$ ~~$c_p(H_2O)$~~ $c_p(H_2O : l) = \frac{75.29}{18}$ J/g·

$C_p(H_2O;l) = 75.29\ J/mol\cdot k$

$\therefore \frac{C_p}{N} = \frac{75.29\ J/k}{6.022\cdot 10^{23}} = \frac{1}{2} f\,(1.38\cdot 10^{-23}\ J/k)$

$\Rightarrow f = 18.11$ !!

**Prob 1.44** $C_p = C_v + Nk = N\frac{f}{2}k + Nk$

$= (\frac{f+2}{2})N\cdot k.$

for monatomic gasses $f = 3$, $\frac{f}{2} = 2.5$; diatomic gasses $f = 5$, $\frac{f}{2} = 3.5$; solids $f = 6$, $\frac{f}{2} = 4$

$N\cdot k = 6.022\cdot 10^{23}\cdot (1.38\cdot 10^{-23}) = 8.31$

$\therefore$

| $C_p$ | | |
|---|---|---|
| monatomic gasses | 20.77 | match well |
| diatomic gasses | 29.0 | match well |
| solids | 33.24 | don't seem to match well |

**Prob 1.45** $w = xy \qquad x = yz$

(a) $w(x,z) = \frac{x^2}{z} \qquad w(y,z) = [redacted]\ y^2 z$

(b) $\left.\frac{dw}{dx}\right|_y = y \qquad \left.\frac{dw}{dx}\right|_z = \frac{2x}{z} = 2y$ Not equal !!

(c) $\left.\frac{\partial w}{\partial y}\right|_x = x$ $\left.\frac{\partial w}{\partial y}\right|_z = 2yz = 2x$

$\left.\frac{\partial w}{\partial z}\right|_x = -\frac{x^2}{z^2} = -y^2$ $\left.\frac{\partial w}{\partial z}\right|_y = y^2$

None!! of the derivatives are equivalent!!

Prob 1.46

(a) $\beta = \frac{1}{V_1}\left.\frac{\partial V}{\partial T}\right|_p$

$\beta = \frac{1}{V_1}\left.\frac{dV_1}{dT}\right|_p \Rightarrow dV_1 = V_1 \beta\, dT$

(b) $k_T = -\frac{1}{V_2}\left.\frac{\partial V}{\partial P}\right|_T$

$dV_2 = -V_2 k_T\, dP$

(c) expands due to temp increase & we compress As change

$\Rightarrow dV_1 = -dV_2$

$V_1 \beta\, dT = V_2 k_T\, dP$ Not actually true that $V_1 = V_2$ but to a good approximation.

$\left.\frac{\partial P}{\partial T}\right|_V = \frac{\beta}{k_T} = \frac{\frac{1}{V}\left.\frac{\partial V}{\partial T}\right|_p}{-\frac{1}{V}\left.\frac{\partial V}{\partial P}\right|_T} = -\frac{(\partial V/\partial T)_p}{(\partial V/\partial P)_T}$

(d) $\beta = \frac{1}{V}\frac{\partial V}{\partial T}\Big|_P$ $\qquad V = \frac{N k_B T}{P}$ $\qquad pV = NkT$

$= \frac{1}{V}\frac{Nk_B}{P} = \frac{1}{V}\frac{V}{T} = \frac{1}{T}$ ideal gas

$k_T = \frac{-1}{V}\frac{\partial V}{\partial P}\Big|_T = \frac{-1}{V}\left(-\frac{Nk_BT}{P^2}\right) = \frac{Nk_BT}{P}\frac{1}{VP} = \frac{1}{P}$. ideal gas

$\frac{\partial P}{\partial T}\Big|_V = \frac{\beta}{k_T} = \frac{1/T}{1/P} = \frac{P}{T} = \frac{Nk}{V}$.

Check $\frac{Nk}{V} \stackrel{?}{=} \left(\frac{-(Nk/P)}{-NkT/P^2}\right) = \frac{P}{T}$ ✓

(e) $\beta = 2.57 \cdot 10^{-4}\,K^{-1}$ $\qquad k_T = 1.81 \cdot 10^{-4}\,K^{-1}$

$\frac{\Delta P}{\Delta T}\Big|_V = +\frac{\beta}{k_T}$

$\Delta P = \frac{\beta}{k_T}\Delta T = \left(\frac{2.57 \cdot 10^{-4}\,K^{-1}}{1.81 \cdot 10^{-4}\,K^{-1}}\right)(10\,K) = 14.19\,Pa$

$=$

$\Delta P_{mercury} = \left(\frac{1.81 \cdot 10^{-4}\,K^{-1}}{4.04 \cdot 10^{-11}\,Pa^{-1}}\right)(10\,K) = 4.48 \cdot 10^{7}\,Pa$

$= .045\,GPa.$

Prob 1.47

$$\Delta Q_{H_2O} + \Delta Q_{ICE} = 0$$

$$\| $$

$$cm\Delta T + c_{Ice} m_{Ice} \Delta T_{ice} + Lm_{Ice} + c_{H_2O} m_{H_2O} \Delta T_{H_2O} = 0$$

to bring $H_2O$ at 100°C to 65°C. | to go from ice at -15°C to ice at 0°C. | to transform ice at 0°C to water at 0°C. | to transform

$$c_{p(H_2O:l)} = \frac{75.29 \text{ J/k mol}}{18 \text{ g/mol}} = 4.18 \text{ J/k·g}$$

$m(H_2O) = 200 \text{ g}$

$\Delta T = 65 - 100 = -35 \text{ k}$

$c_{Ice}\ c_{(H_2O:s)} = .5 \text{ cal/g°C}$

$= 2.093 \text{ J/gk}$

~~cal = 10 J~~

1 cal = 4.186 J

$m_{Ice} = ?$

$\Delta T_{ice} = (0 - (-15)) = 15 \text{ k}$

$L(\text{ice} \Rightarrow H_2O) = 333 \text{ J/g}$

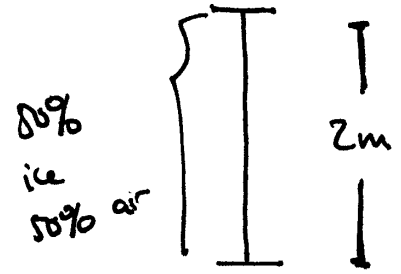
$$\rightarrow (4.18)(200)(-35) + (2.093)m(15) + 333m + (4.18)m(65-0) = 0$$

$$-2.927\cdot10^4 + 31.39\,m + 333m + 271.7\,m = 0$$

$$636.09m = 2.927\cdot10^4$$

$$m = 46.02\,g$$

Prob 1.48




Sunlight $\approx$ 1000 W/m$^2$.

Assume it ½ is ice, then about 1 meter thick of ice is present that would need to be melted.

per meter of ice

req enough heat to melt & turn it to $H_2O$

$$Q = L_{ice\to H_2O}\cdot m$$

$$= (333\ J/g)\,m$$

$$\rho_{ICE} = 0.917\ g/cm^3$$

$$= .917\ g/(10^{-2})^3 m^3$$

$$= .917\cdot10^6\ g/m^3$$

$$= 917\cdot10^3\ g/m^3$$

$$\therefore\ m_{ICE} = (1m)(917\cdot10^3\ g/m^3) = 917\cdot10^3\ g/m^2.$$

Thus $W\Delta t = (333\ J/g)(917\cdot10^3\ g/m^2)$

$$\approx 3.05\cdot10^8\ J/m^2$$

$$\Delta t = 3.53\ \text{days}.$$

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$PV = 3100\,J$

$\Delta H = 40{,}660\,J$ .

$$\frac{PV}{\Delta H} = .076 \approx 8\%$$

Prob 1.49

$1 H_2 + \frac{1}{2} O_2 \rightarrow H_2O.$

$U_{thermal} = \frac{5}{2}(6.022 \cdot 10^{23})(1.38 \cdot 10^{-23})(300)$ { $U_{thermal} = \frac{f}{2} NkT$

$U_{thermal} = \frac{5}{2}(6.022 \cdot 10^{23}\ atoms/mole)(1\ mole)(1.38 \cdot 10^{-23}\ J/K)(300\ K)$ $= \frac{f}{2} nRT$

$+ \frac{5}{2}(6.022$

$= \frac{7}{2} 1 RT + \frac{1}{2} \frac{1}{2} RT = \frac{7}{2} \cdot \frac{3}{2} \cdot RT.$

$= \frac{5}{2} \cdot \frac{3}{2} \cdot (8.314\ J/mol \cdot K)(300\ K) = 9.35 \cdot 10^3\ J$

The PV work done by the atmosphere upon contraction, would be:

$W = -P\Delta V = 1 atm V_0 = n 1 RT = (8.314\ J/mol \cdot K)(300K)$

$+ \frac{1}{2}(8.314\ J/mol \cdot K)(300K)$

$= \frac{3}{2}(2.494 \cdot 10^3) = 3.741 \cdot 10^3\ J.$

Then ~~$\Delta U = -\Delta U_{thermal} +$~~

$\Delta U = -\Delta U_{thermal} + W$

lost — work done by atmosphere

$= -9.35 \cdot 10^3\ J + 3.741 \cdot 10^3\ J = -5.6 \cdot 10^3\ J$ ?

What about thermal energy stored in $H_2O$?

$U_{thermal}$

For liquids $f \approx 3$ ...

$$U_{thermal\ liquid} = \frac{3}{2} NkT$$

$$= \frac{3}{2}(6.02 \cdot 10^{23}\ \text{molecules/mole})(1.38 \cdot 10^{-23}\ \text{J/K})(800\ \text{K})$$

$$= 3.73 \cdot 10^{3}\ \text{J}.$$

$\therefore$ $U_{Before} = U_{thermal\ gas} + \text{work done by atmosph} +$

$U_{After} = U_{thermal\ liquid} + Q_{reaction}$

$$U_{Before} = U_{After} + Q$$

$$Q_{reaction} = U_{thermal\ gas} + \text{work by atmosph} - U_{thermal\ liquid}$$

$$= (9.35 + 3.741 - 3.73)\ \text{kJ}$$

$$= -3.7\ \text{kJ}.$$

? Not correct.

Prob 1.50

reactant product

(a) $CH_4 \longrightarrow C + 2H_2$

$\Delta_f H(C) + 2\cdot\Delta_f H(H_2) - \Delta_f H(CH_4)$

$= 0 + 2\cdot 0 - (-74.81)$ kJ/mole $= 74.81$ kJ/mole

reactant: product:

(b) $C + 2H_2 + 2O_2 \rightarrow CO_2 + 2H_2O$

$\Delta_f H(CO_2) + 2\Delta_f H(H_2O) - \Delta_f H(C) - 2\Delta_f H(H_2) - 2\Delta_f H(O_2)$

$-393.51 + 2(-241.82) - 0 - 2\cdot 0 - 2\cdot 0$

$= -877.15$ kJ/reaction

(c) $CH_4 + 2O_2 \xrightarrow{(1)} C + 2H_2 + 2O_2 \xrightarrow{(2)} CO_2 + 2H_2O$

$\Delta H$(1st reaction) − $\Delta H$(2nd reaction)

$= (-877.15 - 74.81)$ kJ/reaction $= -951.9$ kJ/reaction

(d) Check $\Delta H_f$(reac products) − $\Delta H_f$(products)

$= \Delta H_f(CO_2) + 2\Delta H_f(H_2O) - \Delta H_f(CH_4) - 2\Delta H_f(O_2)$

$= -393.51 + -2(241.82)$

$-(-74.81) - 2(0) = -802$ kJ. Not all the same??

(d) $\Delta H = Q + W_{other}$ (constant P) eq 1.5J.

$\therefore Q_{given\ off} = -802.$ kJ.

(e) $\Delta H = \Delta U + P\Delta V$

$-802\text{ kJ} = \Delta U + (1\text{atm})(V_f - V_0)$ $\qquad V = \frac{nRT}{P}$

$= \Delta U + (1\text{atm})(3\text{mole} - 3\text{moles})$

$= 0.$

This would be different in the following way (assuming vol. of liquid is insignificant)

$-802\text{ kJ} = \Delta U + (1\text{atm})\left(\frac{(1\text{mole})(R)T}{P} - \frac{(3\text{mole})RT}{P}\right)$

$\Rightarrow \Delta U = \ldots$

(f) Assuming the sun was made of entirly methen $CH_4$.

$n = \frac{\text{mass}}{M}$ (molar mass) $= (12+4)\,g/\text{mole}.$

$n = \frac{2\cdot 10^{30}\text{ kg}}{(16\cdot 10^{-3}\text{ kg/mole})} = 1.25\cdot 10^{32}$

Each mole of $C_6H_{12}O_6$ burned produces $-841$ (say) kJ of heat.

$\therefore$ total energy produced

$$(1.25 \cdot 10^{32})(841\ \text{kJ}) = (3.9 \cdot 10^{26}\ \text{W})\,\Delta t$$

$$\Rightarrow \Delta t = 2.69 \cdot 10^{11}\ \text{s} = 8.54 \cdot 10^{3}\ \text{yr}.$$

Prob 1.51

$$\Delta H = 6(-393.51) + 6(-241.82) - 1(-1273) - 0$$

$$= 2.5 \cdot 10^3 \text{ kJ}$$

Prob 1.52

$\Delta H_{comb}$ = 31,000 kcal per gallon gasoline

$\Delta H_{comb}$ = 100 kcal per 28g of cornflakes

1 gallon of gas ≅ $2 (U.S.)

1 Box of cornflakes 14 oz box cost ≈ 2.52.

∴ ~~$/kJ cost~~

So for gas $\left(\frac{2}{31 \cdot 10^6 \text{ cal}}\right) = 6.45 \cdot 10^{-8}$ $/cal

for cornflakes $\frac{2.52}{100 \cdot 10^3 \left(\frac{14}{28}\right)} = 5.04 \cdot 10^{-5}$ $/cal

So per ~~kJ~~ calory gas is cheaper

Prob 1.53 $\Delta H_f$ = 217.97 kJ/mole $\frac{1}{2} H_2 \longrightarrow H$

# of molecules is $\frac{1}{2}(6.022 \cdot 10^{23})$

in this reaction

$$\therefore \quad \Delta H_f = \frac{217.97 \text{ kJ/reaction}}{\frac{1}{2}(6.022 \cdot 10^{23}) \text{ molec/reaction}}$$

$$= 7.23 \cdot 10^{-19} \text{ kJ/molec } H_2$$

1 J = ? eV

$1 eV = 1.602 \cdot 10^{-19}$ J  1 J = 6.2 · $10^{18}$ eV

$\therefore \quad \Delta H_f = 4513$ eV/molecule $H_2$.

Prob 1.54  1 kg = 2.2 lbs.

(a) $E_{at\ top\ (potential)} = mgy$.

$= (60 \text{ kg})(9.8 \text{ m/s}^2)(1500 \text{ m}) = 8.82 \cdot 10^5$ J.

↓

B · (100 kcal) · fact. =

B = 8.42 bowls.

1 kcal =

1 cal = 4.186 J.

(b) Q = $2.6 \cdot 10^6$ J. of energy would have to be dissipated.

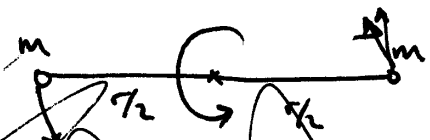
$Q = C_v \Delta T$  What is $C_v$ for a human?

(c) If $Q = 2.6 \cdot 10^6$ J = $m\ell_{H_2O(\ell) \to H_2O(g)}$

$\ell = 980$ cal/g ...

Prob 1.55

(a)




Potential Energy $= -\frac{GM^2}{r^2}$

total KE $= \frac{1}{2}m(\omega\frac{r}{2})^2 + \frac{1}{2}m(\omega\frac{r}{2})^2 = \frac{m\omega^2 r^2}{4}$.

Are $\omega$ & $r$ independent? No. Force to place mass in rotation must be provided by gravitation.

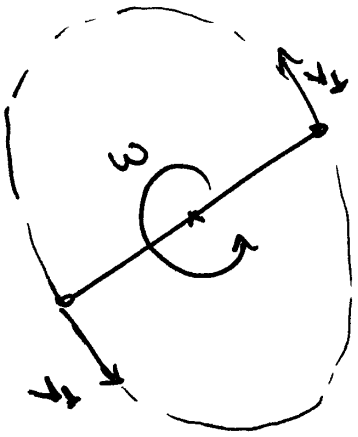
$F = +\frac{Gm^2}{r} =$ centripetal acceleration $= \frac{mv^2}{r} = \frac{m(\omega r/2)^2}{(r/2)}$

$= m\omega^2\frac{r}{2}$

$\therefore \frac{m\omega^2}{2} = +\frac{Gm^2}{r^2} =$ Potential Energy

$\frac{\omega^2}{2} = \frac{Gm}{r^2}$

Prob 1.55




Let $\ell$ = distance between two masses.

$$U_{potential} = -\frac{Gm^2}{\ell} \qquad \& \quad KE_{total} = \frac{1}{2}mv_\perp^2 + \frac{1}{2}mv_\perp^2$$

$$= mv_\perp^2 = m(\omega^2 \ell/2)^2$$

$$= \frac{m\omega^2\ell^2}{4}$$

Now a force Balance on one mass due to the other would give:

$$F_{gravitational} = \frac{Gm^2}{\ell^2} = "\frac{mv_\perp^2}{r}" = \text{centrifugal force}$$

$$= \frac{m(\omega \ell/2)^2}{\ell/2} = m\omega^2\frac{\ell}{2}$$

Thus $$\frac{Gm^2}{\ell} = \frac{m\omega^2\ell^2}{2}$$

$$\| \qquad -U_{potential} = 2KE(total).$$

$$\Rightarrow U_{potential} = -2U_{kinetic}.$$

(b) If one adds simply energy into a system one would expect after equilibration the distribution of

$$\frac{U_{potential}}{U_{kinetic}} = -2.$$

$$U_{potential} + 2U_k = 0$$

$$U^0_{total} = U^0_{potential} + U^0_{kin} \quad \text{and} \quad U_p = -2U_k$$

$$U_{total} + \Delta U = -2U_{kin} + U_k = -U_{kin}.$$

Next one...

(c) $U_{total} = U_{potential} + U_{kin} = -U_{kin} =$

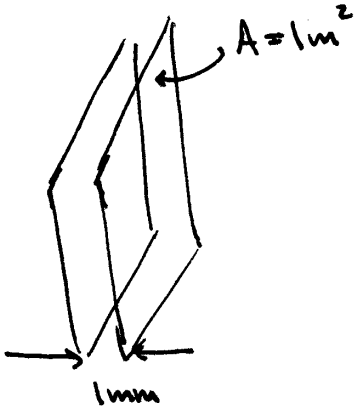
↑ by virial theorem

?

(d) ?

(e) ?

Prob 1.16




$$\frac{Q}{\Delta t} \propto \frac{A\Delta T}{\Delta x} \qquad Q \propto \frac{A\Delta T}{\Delta x}\cdot \Delta t$$

$$\frac{Q}{\Delta t} = -k_t \frac{A\Delta T}{\Delta x}$$

$$\therefore \frac{Q}{\Delta t} = -\frac{(.026\ W/mk)(1m^2)(20k)}{(1mm)}$$

$$= -\frac{(.026\ W/mk)(1m^2)(20k)}{10^{-3}m} = 5.2\cdot 10^2\ W.$$

Prob 1.57 $R = \frac{\Delta x}{kt}$

(a) $R_{glass} = \frac{(3.2\cdot10^{-3}\,m)}{.8\ W/mk} = 4\cdot10^{-3}\ \frac{m^2 k}{W}$

$R_{Air} = \frac{1\cdot10^{-3}\,m}{.026\ W/mk} = 3.84\cdot10^{-2}\ \frac{m^2 k}{W}$.

(b) $\frac{°F\cdot ft^2\cdot hr}{Btu} =$ $\quad T_C = \frac{5}{9}(T_F - 32)$

$1°F = \frac{9}{5}°C = \frac{9}{5}k$

$\therefore$

$1\ (Btu) = (4.53\cdot10^{-1}\,kg)\,C_{H_2O}\,(\frac{9}{5})$ $\quad 1lb = 4.53\cdot10^{-1}\,kg$

$C_{H_2O} = 75.29\ J/k\ (\frac{1\,mole}{18\cdot10^{-3}\,kg})\ \frac{1}{mole} = 4.18\cdot10^{6}\ J/kg$

$\therefore\ 1\,Btu = 3.41\cdot10^{6}\,J$

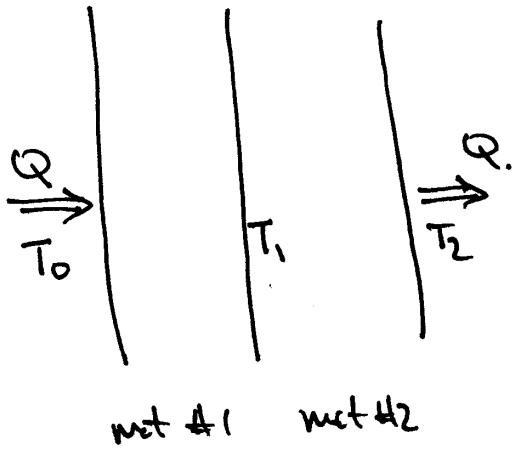
$\therefore\ 1\ \frac{°F\cdot ft^2\,hr}{Btu} = \frac{(\frac{9}{5}k)(.3\,m)^2(3600\,s)}{3.41\cdot10^{6}\,J} = 1.7\cdot10^{-4}\ \frac{m^2 k}{W}$.

$\therefore\ 4\cdot10^{-3}\ \frac{m^2 k}{W} = \frac{23.5}{}\ \frac{°F\cdot ft^2\,hr}{Btu}$

$+\ 3.84\cdot10^{-2}\ \frac{m^2 k}{W} = 225.10^{2}\ \frac{°F\cdot ft^2\,hr}{Btu}$.

Prob 1.57

(c)




$$Q \propto \frac{\Delta t A}{\Delta x}\Delta T \quad \Rightarrow \quad \frac{Q}{\Delta t} = -k\frac{A\Delta T}{\Delta x}.$$

For entire object:

$$\frac{Q}{\Delta t} = -k_{total}\frac{A(T_2-T_0)}{(\Delta x_1+\Delta x_2)}$$

$$\therefore \frac{Q}{A\Delta t} = -\frac{k_{total}(T_2-T_0)}{\Delta x_1+\Delta x_2}$$

For object #1 material #1

$$\frac{Q}{\Delta t} = -k_1\frac{A(T_1-T_0)}{\Delta x_1}$$

$$\frac{Q}{A\Delta t} = -\frac{k_1(T_1-T_0)}{\Delta x_1}$$

For object #2 material #2

$$\frac{Q}{\Delta t} = -k_2\frac{A(T_2-T_1)}{\Delta x_2}$$

$$\frac{Q}{A\Delta t} = -\frac{k_2(T_2-T_1)}{\Delta x_2}$$

$$\Downarrow$$

$$T_1-T_0 = -\frac{\Delta x_1}{k_1}\frac{Q}{A\Delta t}; \quad T_2-T_1 = -\frac{\Delta x_2}{k_2}\frac{Q}{A\Delta t}$$

$$\Rightarrow T_1-T_0 = -R_1\frac{Q}{A\Delta t}; \quad T_2-T_1 = -R_2\frac{Q}{A\Delta t}$$

$$\checkmark$$

Adding:

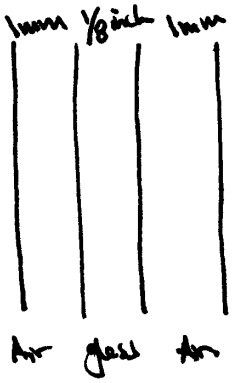
$$T_2 - T_0 = -(R_1 + R_2)\frac{Q}{A\Delta t}$$

$$\therefore \quad Q = -\frac{A\Delta t(T_2 - T_0)}{R_1 + R_2}$$

comparing to $Q = -\frac{A\Delta t(T_2 - T_0)}{R_{total}}$

$$\Rightarrow R_{total} = R_1 + R_2 \ \checkmark$$

(d)




$$R_{effective} = 2R_{air} + R_{glass}$$

$$= 2\left(3.84 \cdot 10^{-2}\ \frac{m^2k}{W}\right) + 4 \cdot 10^{-3}\ \frac{m^2k}{W}$$

$$= 8.08 \cdot 10^{-2}\ \frac{m^2k}{W}.$$

$$\frac{Q}{\Delta t} = -\frac{1}{R_{eff}}(20k)(1m^2)$$

$$= 247.\ W.$$

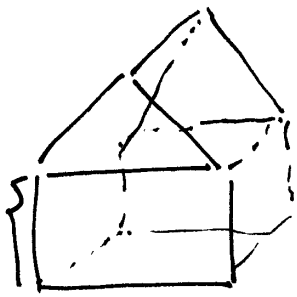
Prob 1.58 From problem 1.57 $R_{\text{Air still}} = 2.25 \cdot 10^2 \ \frac{^\circ F \cdot ft^2 \cdot hr}{Btu}$ per mm.

$R_{\text{Air still 3.5 inch}} = (3.5 \text{ inch} \cdot \frac{? \text{ mm}}{1 \text{ inch}})(2.25 \cdot 10^2 \ \text{---})$

$= (3.5 \cdot 25.4)(\ldots) = 20{,}000.$ !! seems to great?

It Bob gets 1.

Prob 1.59 Est. wood house:



say 1000 sq ft living space w/ 10 ft ceilings. $\approx 10^4 \ ft^3$ of volume

$\approx (10^4)^{2/3}$ A area. Thermal losses due to conduction would be:

$\frac{Q}{\Delta t} = -\frac{k_{wood} A (\Delta T)}{\Delta x}$

estimate $\Delta t = 1$ month

$A = (10^4)^{2/3} \ ft^2$

$k_{wood} = .08 \ W/m \cdot k$

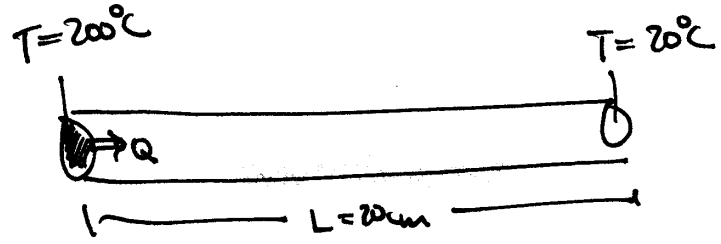
$\Delta T = 30k$

$\Delta x = 3.5$ inch.

$\Rightarrow Q = \ldots$ < Ant heat generated by electricity; Ant heat generated by gas.

.

Prob 1.60




Heat conduction is governed by

$$\frac{Q}{\Delta t} = -kA\frac{\Delta T}{\Delta x} = -kA\frac{dT}{dx}.$$

$\Updownarrow$

constant.

~~$Q = mC_v\Delta T$~~ if no work is done.

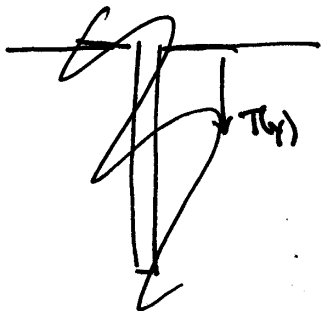
$Q = mC_v\Delta T$

~~$= m C_v \Delta T$~~ $mC_v\Delta T$

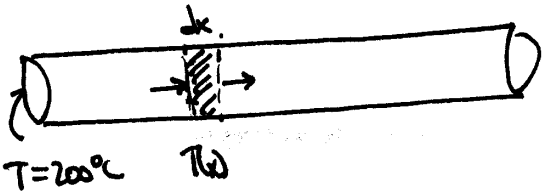
$$\therefore \quad \frac{mC_v\Delta T}{\Delta t} = -kA\frac{dT}{dx}.$$

??

Prob 1.61



Prob1.60




Heat conduction is governed by $\frac{Q}{\Delta t} = -kA\frac{\Delta T}{\Delta x}$

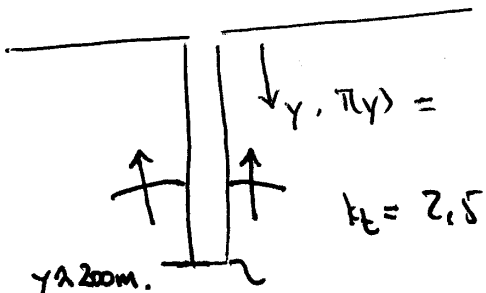
usl $Q = mC\Delta T$

$\Rightarrow$ 8

$mC\,T_t = -kA\,T_x$

$mC\,T_t + kA\,T_x = 0$ ??

Prob 1.61




$T(200m) \cong T_0 + 20(200) = 4\cdot10^3 + T_0$.

$\frac{Q}{\Delta t} \propto \frac{A\Delta T}{\Delta x}$

At 200m ≈ 30 millionths of the radius of the earth.

$\frac{Q}{\Delta t} = -k_t A \frac{\Delta T}{\Delta x}$

$\frac{Q}{A\Delta t}$ = rate of heat conduction per $m^2$. $= -\left(2.5 \frac{W}{m\cdot k}\right)\left(\frac{4\cdot10^3 k}{200\,m}\right)$

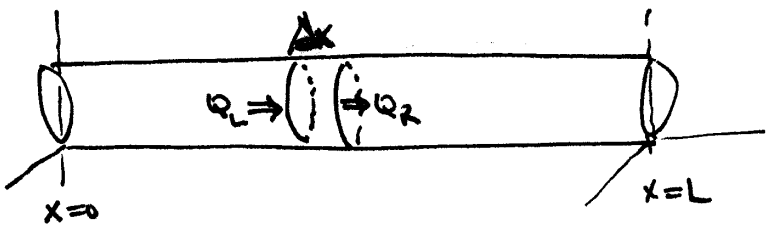
$= -20\cdot 2.5 \frac{W}{m^2}$.

$A_{earth} = 4\pi(6400\,km)^2$

$= 5.14\cdot10^{14}\,m^2$

$Q_{Earth} = 2.57\cdot10^{16}\,W$. seems too large?

Prob 1.62




$\frac{Q}{\Delta t} \propto \frac{A\Delta T}{\Delta x}$ $\quad \frac{Q}{\Delta t} = -k_t A \frac{\Delta T}{\Delta x}$ for instantaneous heat flow.

for steady heat flow

But $Q = E = C_V T$

w/ no work (no PV wk)

$E = Q + W$.

At steady st

$Q_R - Q_L$ = Heat absorbed into the material + stored as thermal energy.

Here $Q_L$ + $Q_R$ or the heat flowing at a given time

$$\therefore \frac{Q_R}{\Delta t} - \frac{Q_L}{\Delta t} = c\rho(A\Delta x)\frac{\Delta T}{\Delta t}$$

↑ Specific heat capacity

⇓ By Fourier's heat flow law, how heat flow affects temperature

$$k_t A \frac{\partial T}{\partial x}\Big|_{x=x_R} + k_t A \frac{\partial T}{\partial x}\Big|_{x=x_L} = c\rho A \Delta x \frac{\partial T}{\partial t}$$

$$\Rightarrow \quad -\frac{1}{I}\frac{\partial^2 T}{\partial x^2} = \left(\frac{c_p}{k_t}\right)\pi_t$$

$$\frac{1}{I}$$

$\pi_t = kTx$ what dat mins sign?

**Prob 1.63** $\quad \ell \approx \frac{1}{4\pi r^2}\left(\frac{V}{N}\right)$ $\quad$ ~~$PV = kNT$~~

$$\frac{V}{N} = \frac{kT}{P}$$

$$\ell \approx \frac{1}{4\pi r^2}\left(\frac{kT}{P}\right)$$

$$\ell \approx 10\,\text{cm} = \frac{1}{4\pi(1.5\cdot 10^{-10}\,m)^2}\left(\frac{1.38\cdot 10^{-23}\,J/k\,(300k)}{P}\right)$$

$$\Rightarrow \quad P = 7.41\cdot 10^{-41}\,Pa.$$

**Prob 1.64** He. is monatomic gas.

$$k_t = \frac{1}{2}\left(\frac{c_v}{V}\right)\ell\bar{v}$$

$$= \frac{1}{2}\left(\frac{\frac{1}{2}Nk}{V}\right)\ell\bar{v} = \frac{1}{2}\left(\frac{\frac{1}{2}P}{T}\right)\ell\bar{v} \cong \frac{1}{2}\left(\frac{\frac{1}{2}P}{T}\right)\ell v_{rms}$$

For a monatomic gas $f = 3$

# Pg 44 Schroeder

07-22-02

**Prob 1.64**

$$k_t = \frac{1}{2}\left(\frac{C_V}{V}\right) l \bar{v}$$

$PV = kNT$

$\frac{V}{N} = \frac{kT}{P}$

$$\frac{C_V}{V} = \frac{\frac{f}{2}Nk}{V} = \frac{f}{2}\frac{P}{VT}$$

$$l = \frac{1}{4\pi r^2}\frac{V}{N}$$

$$= \frac{1}{4\pi r^2}\left(\frac{kT}{P}\right)$$

$$\bar{v} \cong v_{rms} = \sqrt{\frac{3kT}{m}}$$

$$\therefore k_t = \frac{1}{2}\frac{f}{2}\cdot\frac{P}{VT}\cdot\frac{1}{4\pi r^2}\left(\frac{kT}{P}\right)\cdot\sqrt{\frac{3kT}{m}}$$

$$= \frac{1}{4} f \frac{1}{4\pi r^2} k \sqrt{\frac{3kT}{m}}.$$

For Helium (monatomic gas $f = 3$)

$r \cong 1A = 10^{-10}$ m.

$m = ? = \frac{4.00\ g/mole}{6.022\cdot 10^{23}\ Atoms/mole} = 6.64\cdot 10^{-24}\ g/Atom$

$$\therefore k_t = \frac{1}{4}(3)\frac{1}{4\pi(10^{-10}\,m)^2}(1.38\cdot 10^{-23}\,J/k)\sqrt{\frac{3(1.38\cdot 10^{-23}\,J/k)(300\,k)}{(6.64\cdot 10^{-24}\,g/Atom)}}$$

$$k_t = 1.12\cdot 10^{-1}\ \frac{W}{m\cdot k} = .01\ \frac{W}{m\cdot k}.$$

It differs 1) Because the gas is monatomic rather than diatomic

2) The mass of dif

$$\frac{m_{Air}}{m_{He}} = \frac{.7(m_{N_2}) + .3(m_{O_2})}{m_{He}} = \frac{.7(28) + .3(32)}{4} = 7.3!!$$

For some reason this result is not correct w/ Fig 1.19. Perhaps $r \cong 10^{-10}$ m is too small?

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Prob 1.65

$k_t = \frac{1}{4} \cdot 7 \cdot \ldots$

I don't see how to do this w/o & having to know $\ell$, or $\bar{v}$, which I don't think would be desirable

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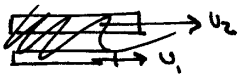
Prob 1.66




As w/ heat conduction

$$\frac{Q}{\Delta t} = -k_D A \frac{dV}{dx}$$

Here Q is PV shearing force work $\Rightarrow Q = F_x \cdot \ell$.

$\therefore \quad F_x \cdot \ell$

$\ldots$ Not sure how to do this $\ldots$

$$\frac{N}{A\Delta t} = D\frac{(N/V)}{\Delta x}$$

$$\frac{\cancel{N}}{\cancel{A\Delta x}\cdot\Delta t} = \frac{D(\cancel{N/V})}{\Delta x^2}$$

$$\frac{1}{\Delta t} = \frac{D}{\Delta x^2} = \frac{10^{-9}\ m^2/s}{(.1m)^2} = \frac{10^{-9}\ m^2/s}{10^{-2}\ m^2} = 10^{-7}\ \cancel{m^2}/s$$

$\Delta t = 10^7\ s$ ✓

Prob 1.67

$$\frac{N}{A\,\Delta t} = D\,\frac{(N/V)}{\Delta x}$$

$$\Rightarrow \quad \frac{1}{A\Delta t} = \frac{D}{V\Delta x} \qquad \text{let } V \simeq A\,\Delta x$$

$\Delta t = 1$ min

$D = 10^{-9}\ m^2/s$

$$\Downarrow$$

$$\frac{1}{\Delta t} \cong \frac{D}{\Delta x^2}$$

$$\therefore \quad \Delta x^2 = \Delta t \cdot D \quad \rightarrow \quad \Delta x \cong \sqrt{D\Delta t} = \sqrt{10^{-9}\ m^2/s \cdot 60\,s} =$$

$$= 2.45 \cdot 10^{-4}\ m$$

$$= .24\ mm.$$

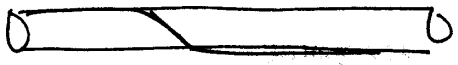
Prob 1.68 Room ~ 30 × 20 $ft^2$.

Roughly $\quad D \cong \frac{\Delta x^2}{\Delta t} \rightarrow \Delta t = \frac{\Delta x^2}{D} = \frac{(30\ ft \cdot \frac{.3m}{1ft})^2}{10^{-9}\ m^2/s}$

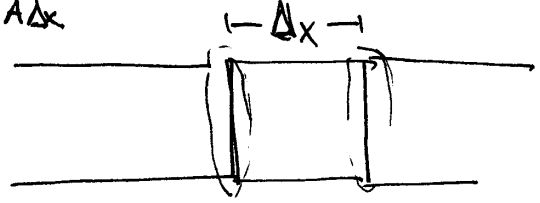
$$\Delta t = 8.1 \cdot 10^{10}\ s. = 2.5 \cdot 10^3\ \text{years.}$$

principle transport mechanism must be convection.

Prob 1.69



$$C(x) = \frac{n(x)}{V} = \frac{n(x)}{A\Delta x} \Rightarrow$$




Now Fick's 1st law is

$$J_x = -D\frac{dn}{dx}$$ flux of particles (i.e. # particles per unit time)

Now concentration in small piece of length $\Delta x$ is given by

$$\frac{n(x)}{} = J_x\Big|_{x_R} - J_x\Big|_{x_L} = -D\frac{dn}{dx}\Big|_{x_R} + D\frac{dn}{dx}\Big|_{x_L}$$

$$= -D\Delta x\,\frac{d^2n}{dx^2}$$

$$\frac{\Delta n(x)}{\Delta t} = J_x\Big|_{x_L} - J_x\Big|_{x_R} = -\left(J_x\Big|_{x_R} - J_x\Big|_{x_L}\right)$$

$$\frac{\Delta n(x)}{\Delta t} = -\left(-D\frac{dn}{dx}\Big|_{x_R} + D\frac{dn}{dx}\Big|_{x_L}\right) = D\left(\frac{dn}{dx}\Big|_{x_R} - \frac{dn}{dx}\Big|_{x_L}\right)$$

$$n_t = D\Delta x\frac{d^2n}{dx^2} \qquad n(x) \equiv A\Delta x \cdot C(x)$$

$$c_t = D\Delta x\frac{d^2c}{dx^2}$$

How do I get rid of this term?

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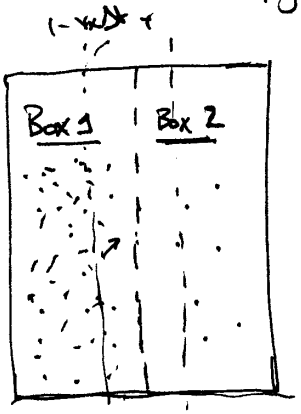
Prob 1.70




# particles crossing from Box #1 into Box #2 in tiny $\Delta t$

$\Delta N$ = Avg # of particles in Box 1 w/ $v_x$ positive + close enough to cross $\bar{v}_x \Delta t$ away − Avg # of particles in Box 2 w/ $v_x$ negative + close enough to cross $\bar{v}_x \Delta t$ away from interface.

$$= \frac{1}{2}(A\bar{v}_x \Delta t)\left(\frac{P}{kT}\right) - \frac{1}{2}(A\bar{v}_x \Delta t)\left(\frac{P}{kT}\right)$$

↑ $\frac{1}{2}$ of all particles have + $v_x$ velocities say.

$$\{ N = \frac{PV}{kT}$$

$$\Rightarrow \frac{\Delta N}{A \Delta t} = \frac{1}{2}\left(\frac{1}{3}\bar{v}\right)\frac{P}{kT} - \frac{1}{2}\left(\frac{1}{3}\bar{v}\right)\frac{P}{kT}$$

Assuming the temperature is the same on both ½'s

$$\bar{v} \approx \bar{v}_{rms} = \sqrt{\frac{3kT}{m}} \qquad \text{Then} \Rightarrow J = \frac{1}{6}\bar{v}\frac{dP}{dx}\cdot \ell$$

$\Rightarrow$ ~~$D \frac{k}{\gamma} =$~~

$$\Rightarrow \quad D = \frac{1}{6}\frac{\bar{v}}{kT}\ell \cdot \cong \frac{1}{6}\frac{v_{rms}}{kT}\ell$$

$$D = \frac{1}{6}\sqrt{\frac{3kT}{m}}\frac{1}{kT}\ell \quad (150\ nm)$$

$$= \frac{1}{6}\sqrt{\frac{3(1.38\cdot 10^{-23}\ J/k)(300k)}{\left(\frac{(72)1 + .3(32)}{6.022\cdot 10^{23}}\cdot 10^{-3}\right)}}\ \frac{150\cdot 10^{-9}\ m}{(1.38\cdot 10^{-23}\ J/k)\cdot 300}$$

$$= 3.05\cdot 10^{15}\ !$$

Maybe this is $D^{-1}$ ? Not very close

Prob 2.1

(a)

| C1 | C2 | C3 | C4 | |
|---|---|---|---|---|
| H | H | H | H | All Heads |
| T | H | H | H | one tail, 3 heads |
| H | T | H | H | |
| H | H | T | H | |
| H | H | H | T | |
| T | T | H | H | two heads. |
| T | H | T | H | |
| T | H | H | T | |
| H | T | T | H | |
| H | T | H | T | |
| H | H | T | T | |
| T | T | T | H | one head |
| T | T | H | T | |
| T | H | T | T | |
| H | T | T | T | |
| T | T | T | T | No heads |

$\binom{4}{2} = \frac{4!}{2!2!} = \frac{4 \cdot 3}{2} = 6$ ✓.

total # of microstates $= 16 = 2^4$

(b) Macrostates would be

4 Heads $P = 1/16$

3 heads $P = 4/16 = 1/4$

2 heads $P = 6/16 = 3/8$

1 head $P = 4/16 = 1/4$

0 heads $P = 1/16$

$$\sum = \frac{1+4+6+4+1}{16} = 1 \checkmark$$

(c) $\Omega(4,0) = \binom{4}{0} = 1$ ✓

$\Omega(4,1) = \binom{4}{1} = 4$ ✓

$\Omega(4,2) = \binom{4}{2} = 6$ ✓

$\Omega(4,3) = \binom{4}{3} = 4$ ✓

$\Omega(4,4) = 1$ ✓.

Prob 2.2

(a) 20 fair coins.

$2^{20}$ microstates

(b) $\frac{1}{2^{20}} = .95 \cdot 10^{-7}$.

(c) $\Omega(20,12) = \frac{\binom{20}{12}}{2^{20}} = \frac{\frac{20!}{8! \cdot 12!}}{2^{20}} = \frac{\frac{20 \cdot 19 \cdot \cdots 13}{8!}}{2^{20}} = \ldots$

(d)

Prob 2.3

(a) $2^{50}$

(b) $\Omega(50,25) = \binom{50}{25}$

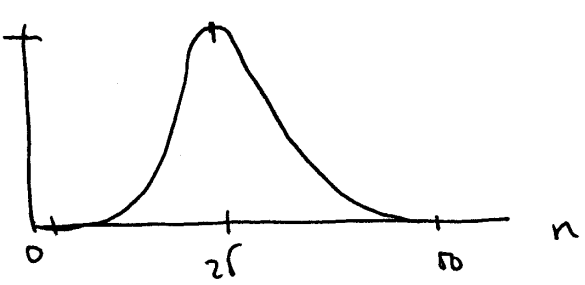
(c) $\frac{\binom{50}{25}}{2^{50}}$

(d) $\frac{\binom{50}{30}}{2^{50}}$

(e) $\frac{\binom{50}{40}}{2^{50}}$

(f) $\frac{1}{2^{50}}$

(g) $\frac{\binom{50}{n}}{2^{50}}$



# Pg 52 Schroeder

Prob 2.4

# hands of cards $\binom{52}{5}$

Prob of getting a royal flush is $\frac{4}{\binom{52}{5}}$.

A, K, Q, J, 10 in each suit

$$\Omega(3,0) = \binom{3-1}{0} = 1$$

$$\Omega(N,q) = \binom{q+N-1}{q}$$

$$\Omega(3,1) = \binom{4-1}{1} = \binom{3}{1} = 3$$

$$\Omega(3,2) = \binom{4}{2} = \frac{4 \cdot 3}{2} = 6$$

$$\Omega(3,3) = \binom{5}{3} = \frac{5 \cdot 4 \cdot 3!}{3!\,2!} = 10 \quad \checkmark$$

Prob 2.25

(a) $N = 3 \quad q = 4$

$$Q(N,q) = \binom{N+q-1}{q}$$

$$= \binom{6}{4} = \frac{6 \cdot 5}{2} = 15.$$

| oscillator | #1 | #2 | #3 |
|---|---|---|---|
| | 4 | 0 | 0 |
| | 0 | 4 | 0 |
| | 0 | 0 | 4 |
| | 3 | 1 | 0 |
| | 3 | 0 | 1 |
| | 1 | 3 | 0 |
| | 0 | 3 | 1 |
| | 1 | 0 | 3 |
| | 0 | 1 | 3 |
| | 2 | 2 | 0 |
| | 2 | 0 | 2 |
| | 2 | 1 | 1 |
| | ~~2~~ | ~~2~~ | ~~0~~ |
| | 0 | 2 | 2 |
| | 1 | 2 | 1 |
| | ~~2~~ | ~~0~~ | ~~2~~ |
| | ~~0~~ | ~~2~~ | ~~2~~ |
| | 1 | 1 | 2 |

B start? 15 states ✓

(b) $N = 3 \quad q = 5$

$$\Omega(N,q) = \binom{N+q-1}{q}$$

$$\Omega(3,5) = \binom{7}{5} = \frac{7 \cdot 6}{2} = 7 \cdot 3 = 21$$

| oscillator | #1 | #2 | #3 |
|---|---|---|---|
| | 5 | 0 | 0 |
| | 0 | 5 | 0 |
| | 0 | 0 | 5 |
| | 4 | 1 | 0 |
| | 4 | 0 | 1 |
| | 1 | 4 | 0 |
| | 0 | 4 | 1 |
| | 1 | 0 | 4 |
| | 0 | 1 | 4 |
| | 3 | 2 | 0 |
| | 3 | 0 | 2 |
| | 3 | 1 | 1 |
| | 2 | 3 | 0 |
| | 0 | 3 | 2 |
| | 1 | 3 | 1 |
| | 2 | 0 | 3 |
| | 0 | 2 | 3 |
| | 1 | 1 | 3 |
| | 2 | 2 | 1 |
| | 2 | 1 | 2 |
| | 1 | 2 | 2 |

21 total ✓

(c) $N = 3 \quad q = 6$

$$Q(N,q) = \binom{N+q-1}{q}$$

$$Q(3,6) = \binom{8}{6} = \frac{8 \cdot 7}{2} = 28$$

oscillator: #1 #2 #3

6 0 0.
0 6 0.
0 0 6.
5 1 0.
5 0 1.
1 5 0.
0 5 1.
1 0 5.
0 1 5.
4 2 0.
4 0 2.
4 1 1.
2 4 0.
0 4 2.
1 4 1.
2 0 4.
0 2 4.
1 1 4.
3 3 0.
3 0 3.
3 2 1.
3 1 2.
3 3 0.
0 3 3.
2 3 1.
1 3 2.
~~3 0 3~~ x
~~0 3 3~~ x
2 1 3.
1 2 3.

28 total

(d)

$N=4 \quad q=2$

$\Omega(N,q) = \binom{N+q-1}{q}$

$\Omega(4,2) = \binom{5}{2} = \frac{5\cdot 4}{2} = 10$

| oscillator | #1 | #2 | #3 | #4 |
|---|---|---|---|---|
| | 2 | 0 | 0 | 0 |
| | 0 | 2 | 0 | 0 |
| | 0 | 0 | 2 | 0 |
| | 0 | 0 | 0 | 2 |
| | 1 | 1 | 0 | 0 |
| | 1 | 0 | 1 | 0 |
| | 1 | 0 | 0 | 1 |
| | 0 | 1 | 1 | 0 |
| | 0 | 1 | 0 | 1 |
| | 0 | 0 | 1 | 1 |

/10 ✓

(e) $N=4 \quad q=3$

$\Omega(4,3) = \binom{6}{3} = \frac{6\cdot 5\cdot 4}{3\cdot 2} = 20$

| oscillator | #1 | #2 | #3 | #4 |
|---|---|---|---|---|
| | 3 | 0 | 0 | 0 |
| | 0 | 3 | 0 | 0 |
| | 0 | 0 | 3 | 0 |
| | 0 | 0 | 0 | 3 |
| | 2 | 1 | 0 | 0 |
| | 2 | 0 | 1 | 0 |
| | 2 | 0 | 0 | 1 |
| | 1 | 2 | 0 | 0 |
| | 0 | 2 | 1 | 0 |
| | 0 | 2 | 0 | 1 |
| | 1 | 0 | 2 | 0 |
| | 0 | 1 | 2 | 0 |
| | 0 | 0 | 2 | 1 |

| #1 | #2 | #3 | #4 |
|---|---|---|---|
| 1 | 0 | 0 | 2 |
| 0 | 1 | 0 | 2 |
| 0 | 0 | 1 | 2 |
| 1 | 1 | 1 | 0 |
| 1 | 1 | 0 | 1 |
| 1 | 0 | 1 | 1 |
| 0 | 1 | 1 | 1 |

/20 ✓

(f) $N=1$ $q=$ anything

oscillator #1

$q$.

$$\Omega(N,q) = \binom{1+q-1}{q} = \binom{q}{q} = 1$$

(g) $N=$ anything, $q=1$

$$\Omega(N,q) = \binom{N+1-1}{1} = N$$

Prob 2.6

$$\Omega(30,30) = \binom{30+30-1}{30} = \binom{59}{30} = \frac{59!}{30!\,29!}$$

$$= 59 \cdot 58 \cdots$$

Prob 2.7 $N=4$ $q=2$

$$\Omega(N,q) = \binom{5}{2} = \frac{5\cdot 4}{2} = 10$$

| #1 | #2 | #3 | #4 | dot & line representation |
|---|---|---|---|---|
| 2 | 0 | 0 | 0 | ••\|\|\| |
| 0 | 2 | 0 | 0 | \|••\|\| |
| 0 | 0 | 2 | 0 | \|\|•-•\| |
| 0 | 0 | 0 | 2 | \|\|\|•• |
| 1 | 1 | 0 | 0 | •\|•\|\| |
| 1 | 0 | 1 | 0 | •\|\|•\| |
| 1 | 0 | 0 | 1 | •\|\|\|• |
| 0 | 1 | 0 | 1 | \|•\|\|• |
| 0 | 0 | 1 | 1 | \|\|•\|• |
| 0 | 1 | 1 | 0 | \|•\|•\| |

$q_{total} = 6 = q_A + q_B$

$\Rightarrow$ # how many macro states? in $q_A$ we can have $0, 1, \cdots, 6 \rightarrow 6+1$

macro states. w/ macrostates being able to be distin