Equations from the end of each chapter

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

$$\Delta A = 2\alpha A \Delta T$$

$$\Delta V = \beta V \Delta T \sim 3\alpha V \Delta T$$

$$Q = mc\Delta T$$

$$Q_{\text{cold}} + Q_{\text{hot}} = 0$$

$$Q = mL_{\text{f}}$$

$$Q = mL_{\text{v}}$$

$$P = \frac{kA(T_h - T_c)}{d}$$

$$P_{\text{net}} = \sigma e A\left(T_2^{\,4} - T_1^{\,4}\right)$$

$$pV = Nk_{\text{B}}T$$

$$\Delta U = nC_{\text{V}}\Delta T$$

$R = 8.3145$ J/mol/K

$K = 1.38 \cdot 10^{-23}$ J/molecule/K

$\rho = m/V$

$g = 9.80$ m/s^2

$P_{\text{atm}} = 1.013 \cdot 10^5$ Pa

$T_{\text{ice}} = 273.15$ K

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$$

$$pV = nRT$$

$$\left[p + a\left(\frac{n}{V}\right)^2\right](V - nb) = nRT$$

$$pV = \frac{1}{3}Nm\overline{v^2}$$

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_{\text{B}}T}{m}}$$

$$\lambda = \frac{V}{4\sqrt{2}\pi r^2 N} = \frac{k_{\text{B}}T}{4\sqrt{2}\pi r^2 p}$$

$$\tau = \frac{k_{\text{B}}T}{4\sqrt{2}\pi r^2 p v_{\text{rms}}}$$

$$\bar{K} = \frac{3}{2}k_{\text{B}}T$$

$$E_{\text{int}} = \frac{3}{2}Nk_{\text{B}}T.$$

$L_{\text{f,water}} = 334 \cdot 10^3$ J/kg

$$Q = nC_V \Delta T$$

$$C_V = \frac{d}{2}R$$

$$f(v) = \frac{4}{\sqrt{\pi}}\left(\frac{m}{2k_{\text{B}}T}\right)^{3/2} v^2 e^{-mv^2/2k_{\text{B}}T}$$

$$\bar{v} = \sqrt{\frac{8}{\pi}\frac{k_{\text{B}}T}{m}} = \sqrt{\frac{8}{\pi}\frac{RT}{M}}$$

$$v_p = \sqrt{\frac{2k_{\text{B}}T}{m}} = \sqrt{\frac{2RT}{M}}$$

$$f(p, V, T) = 0$$

$$W = \int_{V_1}^{V_2} p\,dV$$

$$E_{\text{int}} = \sum_i (\bar{K}_i + \bar{U}_i),$$

$$E_{\text{int}} = nN_{\text{A}}\left(\frac{3}{2}k_{\text{B}}T\right) = \frac{3}{2}nRT$$

$$\Delta E_{\text{int}} = Q - W$$

$$C_p = C_V + R$$

$$\gamma = C_p / C_V$$

$$pV^\gamma = \text{constant}$$

$$W = Q_{\text{h}} - Q_{\text{c}}$$

$$e = \frac{W}{Q_{\text{h}}} = 1 - \frac{Q_{\text{c}}}{Q_{\text{h}}}$$

$$K_{\text{R}} = \frac{Q_{\text{c}}}{W} = \frac{Q_{\text{c}}}{Q_{\text{h}} - Q_{\text{c}}}$$

$$K_{\text{P}} = \frac{Q_{\text{h}}}{W} = \frac{Q_{\text{h}}}{Q_{\text{h}} - Q_{\text{c}}}$$

$$e = 1 - \frac{T_{\text{c}}}{T_{\text{h}}}$$

$$K_{\text{R}} = \frac{T_{\text{c}}}{T_{\text{h}} - T_{\text{c}}}$$

$$K_{\text{P}} = \frac{T_{\text{h}}}{T_{\text{h}} - T_{\text{c}}}$$

$$\Delta S = \frac{Q}{T}$$

$$\Delta S = S_B - S_A = \int_A^B dQ/T$$

$$\oint dS = \oint \frac{dQ}{T} = 0$$

$$\Delta S \geq 0$$

$$\lim_{T \to 0} (\Delta S)_T = 0$$

Exam 3 S13 Phys 1220 (borrowed from Prof. Michalak)

1. **Thermodynamics**

An insulated beaker of negligible mass contains 1 [kg] water at 77°C. The volume of the beaker is cylindrical with cross sectional area 6.24 [cm^2] and height 10 [cm]. The system is being cooled by adding ice.

a) Which statements about this process are true? (Mark all which apply)

A- There is no energy exchange between the system and the environment.

Skip B! B- The internal energy, U, of the system water and ice is constant as the water cools.

Skip C! C- In order to calculate the total heat transfer, 4 different heat transfer terms have to be considered, addressing the different phases, etc.

D- There is no latent heat release involved in the process.

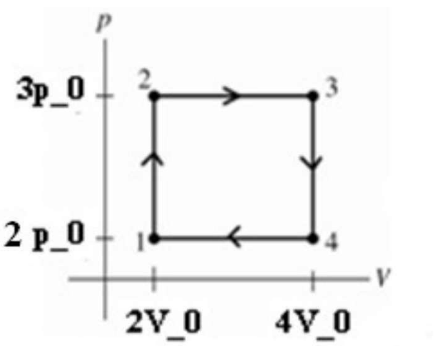
E- The volume of the beaker plays no role in the calculation.

F- Mechanical work is done on the ice.

b) How many kg ice at T = -23°C must be added to make the system temperature T_{final}= +27°C?

2. **First Law of Thermodynamics**

An engine takes 2 moles of an ideal diatomic gas through the cycle (1-4) shown in the figure. $C_v = \frac{5}{2} R(diatomic\ ideal\ gas)$



Hint: $C_P = C_V + R$. Express your results in multiples of p_0V_0.

a) Find the Work done ***in each*** process

b) Find the heat absorbed or released ***in each*** process

c) Compare your results to those one gets from a geometrical analysis of the plot for the total work and total heat for the cyclical process. Explain how W_{tot} and Q_{tot} relate and why they relate that way.

3. **Thermodynamics**

A straight composite rod consists of a 1[m] long section of steel and a section of copper of unknown length. Both parts have the same cross section: 2 [cm] by 2 [cm]. The rod is completely insulated except at the end plates: they are immersed in boiling water (steel) and ice water (copper).

a) How long (in meters) does the copper section have to be so that the steady state temperature at the steel-copper joint is 50[°C]?

We watched a number of videos in lecture and demonstrations regarding thermodynamic processes that occur, which take a substance along a path in a phase diagram. Among these were:

- fast freezing water in a long enclosure of which one end is cooled by liquid nitrogen;
- water that starts boiling when ice is added to the outside of its closed container;
- water that starts boiling when a vacuum pump evacuates the gas on top of the water;
- a cotton ball that ignites when a piston is moved.

b) Explain two of these demonstrations and draw for each the path the water takes in the p-V and in the p-T diagram.

Skip b!

4. **Thermodynamics: conceptual**

Two equal size boxes, A and B, contain ideal gases. An inserted thermometer shows $T_A = 50^0C$ and $T_B = 10^0C$. This is all we know about the gas in the boxes.

Which of the following statements must be true? Could be true? Must be false? Explain your reasoning.

a) The pressure in A is higher than the pressure in B.

b) A and B do not contain the same type of gas.

c) The molecules in A have more average kinetic energy per molecule than those in B.

d) The average speed of the molecules in A is larger than that of the molecules in B.

Skip e!

e) If the molecules have the same mass, the density of the molecules in B is larger than the density in A.

Skip f!

f) The mean free path of the molecules could be the same in both containers.

Skip 5!

5. **Thermodynamics: conceptual**

An ideal container with a tight fitting lid is partially filled with water at +80^{0}C. The container and its content are then heated slowly, in such a manner that everything remains near thermal equilibrium at all times.

The container is first heated to +110^{0}C. Then the lid is slowly raised to double the volume available to the material inside the container. Next, the same amount of heat that was added to raise the temperature of the H_2O inside the container from 80^{0}C to 110^{0}C is now withdrawn.

a) Sketch these processes described above in a p-T ***and*** in a p-V diagram.

b) Assume that heat is added and withdrawn at one and the same constant rate during all processes that pertain to heat flow. Draw a qualitatively correct diagram of temperature as function of time of the processes.

Now consider processes, which keep the material in the gas phase:

c) Recall the quasi-static processes: iso-thermal, iso-baric, iso-choric/volumetric, and adiabatic. Devise two combinations of quasi-static processes, which bring the H_2O vapor in the container from a common initial point to a common final point in the p-V diagram. Draw the processes in a p-V diagram. Explain which of the combinations you chose requires more work and which requires more heat flow than the other. In each partial process of each combination, is heat entering or leaving and is work done on or done by the gas? Explain your reasoning.