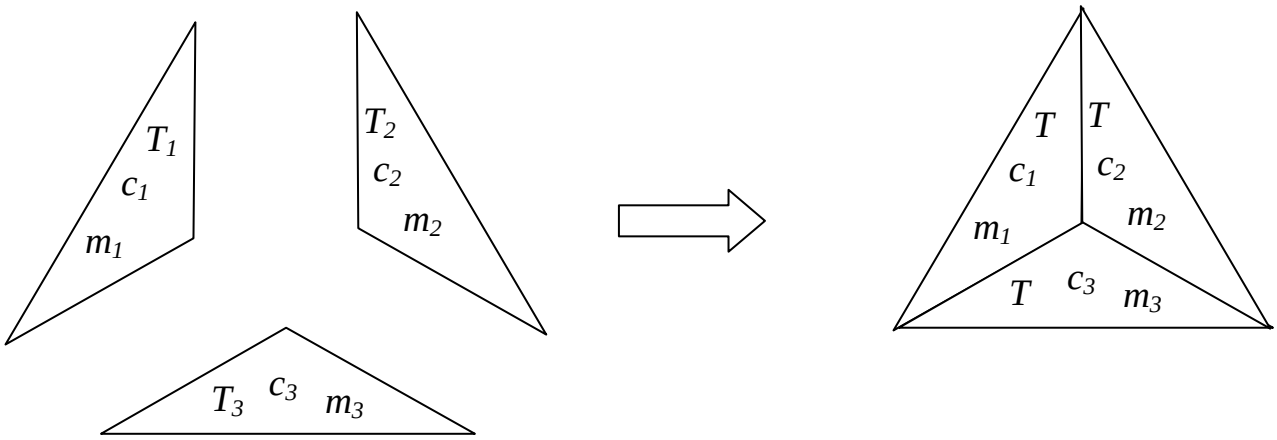
1. Thermo (Undergraduate)

Three incompressible blocks (see figure), of masses, specific heats at constant volume, and temperatures, m_i, c_i , T_i, (i = 1,2,3) are contained within an isolated chamber. Show that if the three blocks are brought into thermal contact, then the change in entropy in the process of thermal equilibration is necessarily positive.



2. Quantum mechanics (Undergraduate)

A particle of charge q and mass m, is moving in a one-dimensional harmonic potential of frequency ω. The particle is subject to a *weak* electric field E.

Find the energy eigenvalues of the system
(a) By exact solution of the Schroedinger equation;
(b) By calculate the first nonzero correction using perturbation theory.

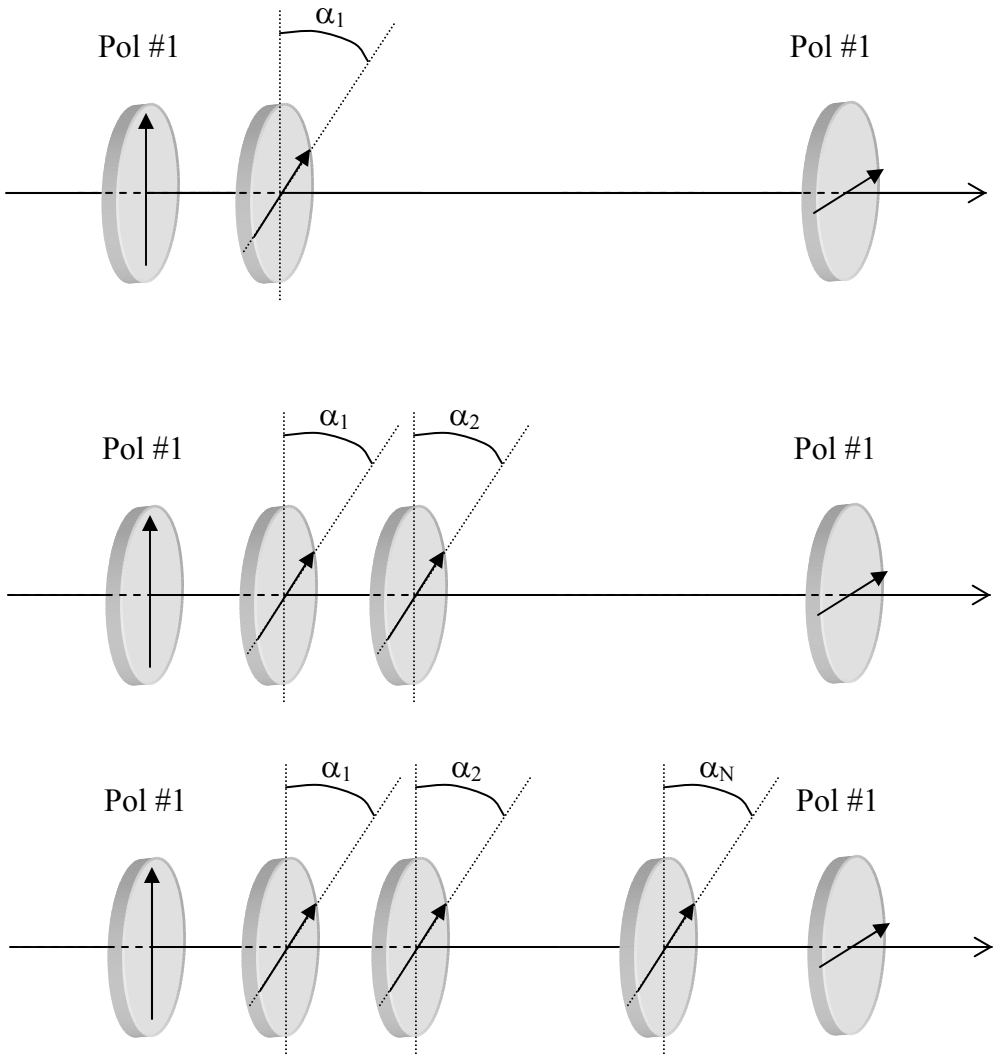
3. Special topic – Optics. (Undergraduate to graduate)

(a) Figure 1 shows a non-polarized optical beam passing through an optical system consisting of two crossed polarizers. A third freely rotating polarizer is placed between of the two. Considering all polarizers to be ideal, i.e. without any spurious absorption or scatter. At what angle α_1 is the transmitted intensity the largest? What is the largest transmitted intensity?

(b) Figure 2 shows a similar arrangement but with two freely rotationg polarizers. At what angles α_1, α_2, is the transmitted intensity the largest and what is the largest transmitted intensity?

(c) The same as in (b) but with N polarizers at angles, α_1, α_2, α_3,... α_N .

(d) What is the transmitted intensity in the limit $N \rightarrow \infty$



4. Math. (See CRC p. 663)

Consider function:

$$\psi(x) = \begin{cases} 1 & if \;\; 0 < x < \frac{1}{2} \\ -1 & if \;\; \frac{1}{2} < x \le 1 \\ 0 & otherwise \end{cases}$$

Haar functions are defined as follows:

$$\psi_{jk}(x) = \psi(2^j x - k),$$

where $j = 0,1,2,...,N$ and $0 \le k \le 2^j - 1$.

a) Graph first seven functions, $\psi_{00}, \psi_{01}, \psi_{10}, \psi_{02}, \psi_{20}, \psi_{12}, \psi_{21}$;

b) Show that Haar's functions are orthogonal with respect to the scalar product defined as:

$$\left\langle \psi_{jk}, \psi_{lm} \right\rangle = \int_0^1 \psi_{jk}(x')\psi_{lm}(x')dx'.$$

5. Thermo. (Undergraduate).

The glow element of 24 V incandescent lamp is made 0.1 mm diameter tungsten wire. At nominal temperature, T=3200 ^{0}C the lamp consumes 100W of electrical power. **Specific electrical resistance** of tungsten is, $\rho = \rho_0 + \alpha(T - T_0)$, where T_0=20 ^{0}C, ρ_0 = 5.5 10^{-8} Ω m, α=2.7 10^{-10} Ω m K^{-1}. The emitted black body radiation constitutes 40% of the consumed electrical power, independent of the temperature. Density of tungsten is ρ_m=19.3 g cm^{-3}, and specific heat is c_p=1.67 J K^{-1} g^{-1}.

How long does it take for the wire to heat up to T=3200 ^{0}C, if at the moment the lamp is switched on the temperature is T=20 ^{0}C ?