Problem 1: Optical resonators

(a) A Fabry-Perot etalon has two parallel mirrors with the same reflectivity $R$, the cavity spacing is $d$ and the refractive index of the cavity is $n$. What is spacing between adjacent resonance frequencies? How does the width of the resonance change with increasing $R$?
(b) Derive the ABCD matrices of a thin lens with focal length equal to $f$, by considering the focusing nature of the thin lens. i.e. parallel rays intersect at the focal plane after passing through a thin lens.

Problem 2: Three- and four-level lasers

(a) Draw the energy-level diagram of an idealized three-level and four-level lasers.
(b) Explain why it is easier to achieve population inversion in a four-level laser.
(c) What wavelength photon can cause an electron to fall from a $-18$ev energy level to a $-20$ev energy level, with emission of a second photon? What is the wavelength of the second photon?

Problem 3: Electro-optic modulator

As shown in the above figure, a phase modulator. e.g. Pockels cell, placed in one branch of a Mach-Zehnder interferometer can serve as an intensity modulator. Assume the Pockels cell length is $L$, the voltage $V$ is applied to the cell separated by distance $d$, the Pockels coefficient is $r$, and the operation wavelength is $\lambda_0$. Both beam-splitters are 50% beam-splitters.

(a) What is the half-wave voltage?
(b) Derive the relationship between transmittance of the modulator ($I_0/I_i$) and the applied voltage $V$.
(c) What is the condition that this device can be treated as a linear intensity modulator?