Laser Physics PHGN480
Midterm - take home: due tuesday 23 Nov at end of day.

- **problem 1**
  Resonator design for HeNe laser
  The tube in a HeNe laser has a diameter of 4mm and a length of 100mm.

  a) what mirror separation and radius of curvature would be required for a confocal resonator to have a stable mode radius of 1mm?

  b) For this cavity, how many longitudinal modes would lie under the bandwidth of 1.5GHz?

  c) If you place a glass (n = 1.5) etalon (Fabry-Perot) in the cavity to select a single longitudinal mode, what would be its optimum thickness?

  d) If the unsaturated gain per pass through the laser tube is 1.02, the output coupling is 1% and the internal loss (not including the output coupler) is 0.5%, calculate the following parameters:
  N_c: **critical inversion density**
  R_{cp}: **critical pumping rate**
  R_p: **effective pumping rate**
  ϕ_0: **circulating number of photons**
  P_{out}: **output power**

  e) What would be the optimum value of the transmission of the output coupler?

- **problem 2**
  The equations governing the dynamics of an ideal 4-level laser oscillator can be represented as
  $$\frac{d N_{\mathrm{inv}}}{d t} = R_p - B \phi N_{\mathrm{inv}} - \frac{1}{\tau} N_{\mathrm{inv}}$$
  $$\frac{d \phi}{d t} = \left(B V_a N_{\mathrm{inv}} - \frac{1}{\tau_c}\right) \phi$$
  (Svelto eqns 7.2.16).

  It is sometimes more convenient to recast these equations so that the variables are an effective round trip gain factor g' and the intracavity circulating power P_L. The gain factor is defined as $g' = \frac{\tau_c}{T_{\mathrm{rt}}} 2 g l$, where $g = \sigma N_{\mathrm{inv}}$is the gain coefficient, T_{rt} is the cavity round trip time, and l is the length of the gain medium. The intracavity power is related to the photon number through $\phi = \frac{P_L T_{\mathrm{rt}}}{h \nu}$.

  Show that the oscillator equations can be written in the following form:
  $$\tau \frac{d}{d t} g' = \frac{P_p}{P_{\mathrm{th}}} - g'\left(2 \frac{P_L}{P_{\mathrm{sat}}} + 1\right)$$
  $$\frac{d P_L}{d t} = -\frac{1}{\tau_c} \left(1 - g'\right) P_L$$

  Other definitions:
  P_p: **pump power**
  P_{th}: **threshold pump power**
  $P_{\mathrm{sat}} = I_{\mathrm{sat}} A_b = \frac{h \nu}{\sigma \tau} A_b$: **saturation power**
  A_b: **area of laser beam in active medium.**