Study guide for Laser Physics in-class midterm.

You may bring in one sheet of paper with anything on it that you want. You should bring a calculator.

Basic knowledge:

- Converting among λ , ω and ν ; converting among widths $\Delta\lambda$, $\Delta\omega$ and $\Delta\nu$
- Making simple approximations: $(1+\varepsilon)^n \approx 1+n\varepsilon$, small argument sin( ), cos( ), exp( ).
- How to calculate intensity, e.g. from energy, beam area and pulse duration

Interaction of light with atoms: Ch 1-5 Hooker and Webb

Cavity modes and blackbody radiation

- Simple 1-D cavity/resonator: how to derive discrete allowed k's, longitudinal mode spacing
- Boltzmann distribution: relative excitation density of two states under thermal equilibrium: $\frac{N_2}{N_1} = \frac{g_2}{g_1}\exp\left(-\frac{E_2 - E_1}{k_B T}\right)$

Einstein A and B coefficients

- Relation of B_{12} to B_{21}, and A_{21} to B_{21}.
- How to know when spontaneous emission is more likely than emission stimulated by blackbody radiation.
- Constructing and working with simple rate equations that include spontaneous emission, absorption, stimulated emission and external pumping rates, e.g. section 2.2.1 or 2.4.1 (using A, B coeff), or section 5.1.1 using cross-sections. Finding relations under steady-state conditions.

Line broadening, line shapes

- Normalized Lorentzian and Doppler (Gaussian) lineshapes.
- Which mechanisms lead to which lineshapes; qualitative difference between homogeneous and inhomogeneous broadening.
- Natural broadening: linkage of exponential damping with Lorentzian lineshape, damping rate with linewidth.
- Decay rate from a single level is the sum of all rates out to destination levels

Cross-sections: gain and absorption

- cross-section σ is particular to a given process: the cross-section will depend on initial and final states, as well as whether it is for absorption or stimulated emission.
- The absorption or gain coefficient is $N\sigma$, where N is the number density of the species involved (e.g. inversion density for gain, where $N = N^*$).
- Definition of inversion density

- Exponential behavior of light growth or decay as light propagates in a gain or absorbing medium.
- Role of upper state lifetime as the storage time for gain.
- Calculation of stored, extractable energy (# excited atoms/volume, *lasing photon energy).
- Calculation of small signal gain by various methods: inversion density, cross-section and length; stored energy fluence and saturation fluence (both energy/area).
- How spectral dependence of the cross-section affects gain or absorption. Spectral or spatial gain narrowing. For absorption, the related concept of optical thickness where strong absorption broadens absorption lineshape because of strong attenuation of the line center.

Saturation fluence, saturation intensity

- steady-state (CW) gain:
  small signal, spectrally-dependent gain $G_0(\omega-\omega_0)=\exp\left[\alpha(\omega-\omega_0)z\right]$
- gain coefficient: $\alpha(\omega-\omega_{21})=N^*\sigma_{21}(\omega-\omega_{21})$, where the cross-section includes the appropriate lineshape and broadening
- Saturated gain: $G(I)=\dfrac{G_0}{1+I/I_s}$, G_0 and the saturation intensity I_s in general depend on the frequency difference $\omega-\omega_{21}$
- Understand that saturation is physically necessary because it is impossible to extract more energy or power from the medium than what it pumped into it.