Problem 1

> *Compare and contrast plasma emission and flourescence.*

Plasma emission is caused by heating a sample to high temperatures causing excitation, where flourescence is caused by more direct excitation and can be produced using light. In both cases the light produced is energy being ejected from an electron transtitioning back to a lower energy state. Plasma emission produces very tight bands. We interact with both, with flourescent bulbs and neon lighting both using the different methods.

Problem 2

> *Describe the ruby crystal structure and its elements. Which element is responsible for the fluorescence and what does it replace?*

Ruby crystal is a form of doped corundum, which is Al_2O_3 in a hexagonal-rhombohedral repeating lattic1e where every oxygen atom is connected to 6 other oxygen atoms. The doping moleule chromium replaces about 1 in 100 aluminum molecules, and is responsible for the flourescence of the ruby. This is caused by three unpaired 3d electrons of Cr^{3+} compared to Al^{3+} upsetting the perfect stability of the corundum crystal structure.

Problem 3

> *Briefly explain population inversion in a lasing medium. What does the lifetime of an energy level have to do with it?*

Population inversion what happens when most atoms in a material are in a higher energy state instead of the natural lower energy state. The ability to generate a population inversion on a sample is dependent on the lifetime of the energy levels available within the material. Typically in a laser the atoms are excited to a short-lived higher energy state which decays quickly into a meta-stable energy state. Molecules in the meta-stable energy state are then able to become the new dominant population, as we can continually pump in excitation light to bring the molecules to the higher-energy state.

Problem 4

> *Briefly describe the differences between spontaneous emission and stimulated emission.*

Most briefly, spontaneous emission happens spontaneously and stimulated emission is stimulated. Importantly, stimulated emission is stimulated by another photon matching the energy level difference, and results in the production of a photon of the exact same wavelength, direction, and phase, contrasted with spontaneous emission which is fully random in phase and direction.

Problem 5

> *What percentage of visible light is passed through a 3 mm thick window made of fused silica (SiO2)?*
> *What percentage of light is passed through a 0.1 mm thick clear Mylar (polyethylene) plastic sheet?*
> *Which transmits more light? Assume absorption is zero. Compute and explain.*

$$n_{silica} = 1.4585$$

$$n_{polyethelene} = 1.500$$

$$R = \left(\frac{1-n}{1+n}\right)^2$$

$$R_{silica} = 0.03478$$

$$R_{polyethelene} = 0.04$$

When $\alpha = 0$,

$$T = (1-R)^2$$

$$T_{silica} = 93.2\%$$

$$T_{polyethelene} = 92.2\%$$

Silica transmits more light, as we can see by comparing T. This makes sense given the larger difference in n going from vacuum to polyethelene than vaccuum to silica.

Problem 6

> *In designing a laser diode (LD), what elements are required to produce blue light?*

Gallium nitride is required to produce blue light.

Problem 7

> *Why do we need a green laster for the lab?*

If we want to stimulate flourescence, it's much harder to use white light since it is made up of a scattering of frequencies, and we may not be able to produce a high enough energy light for the specific absorption we're looking for. A green laser does have a high enough energy to excite R-line flourescence.

Problem 8

> *Can you replace the green laser with a red or blue laser to excite the R-line fluorescence?*

One explanation for why a red laser couldn't be used is that rubies, being red, do not absorb red light. Another explanation is that for flourescence to occur, we must hit the sample with higher energy than will be emitted. Since the atom will excite to a short-lived state, then decay to a meta-stable state from which it will produce a photon of wavelength in the red light range, if the original photon exciting the atom was also red light that would violate conservation of energy as the atom lost more energy than it gained, due to the extra meta-stable state.
The energy of a photon is given by hc/λ, where hc is planck's constant * the speed of light in eV*nm. The lower the wavelength, therefore, the higher the energy of the photon. Blue light is on the lower-wavelength end of the spectrum, as it is close to ultra-violet. This means that a blue laser would have higher energy light than a green laser, and could be used for this experiment.

Problem 9

> *Depending on the relative positions of a lens and an object, the image produced by a convex lens could be real, imaginary or no image. What type of image is produced by the following:*
> *a. the object is further than the focal length;*
> *b. the object is at the focal length;*
> *c. the object is less than the focal distance.*

a. Real image b. No image c. Imaginary image

Problem 10

> *Briefly describe how a spectrometer works.*

Light is passed through a narrow slit, serving as a short-pass filter. The light is then collimated and passed through a grating. This grating disperses the light at different angles depending on its wavelength, like a prism. These components are then focused again onto a detector.