Problem #1. Let’s look at the stellar populations you’re dealing with in a little more detail. Assume that the initial star formation event (the big one) was 10% efficient. That is, the total stellar mass accounts for 10% of the gas mass. Assume we started with a metallicity that was 0.1 solar across the board (i.e. everything heavier than He). What do you need to know in order to calculate the abundance of C, O, Mg, and Fe in the galaxy just before the second burst of star formation? Do the calculation, but leave your specific unknowns as variables. Hint: what kinds of stars have already left the main sequence and are now either planetary nebulae or have already turned into supernovae?

Problem #2. The globular cluster ω Cen shows that it has a range of metallicity, suggesting that later generations of stars formed from material enriched by an earlier generation of planetary nebulae and AGB stars but not supernovae. Approximately what mass-to-light ratio must ω Cen have in order to show this kind of spread in the metallicity?

Problem #3. Use the virial theorem (and other simplifying assumptions) to derive an expression for the fundamental plane of elliptical galaxies.

Problem #4. The Sloan Digital Sky Survey employs photometric techniques to identify high-redshift quasars and distinguish them from other distant galaxies and faint nearby stars. For example, so-called “i-band” dropouts are thought to be luminous quasars at redshifts greater than 5.8. However, one must use J-band photometry to separate L and T type stars from the high redshift quasars.

a) Show why one can use photometric techniques to select quasars at specific redshifts between 4.0 and 6.0, and why L and T type stars might be a problem.

b) Let’s consider your galaxy as it looked just before the second burst. Assume that galaxies exactly like this reside at a redshifts of 2, 3, 4, and 5. What would the observed Gunn r, i, and z magnitudes of these four galaxies be? Play around on the Sloan web page (sdss.org) to find out all about the Gunn filter system. You can base you answer on observations of real galaxies that might look at least a little like your model galaxy.

c) Using your stellar population model and your knowledge of the wide variety of optical photometric systems, devise a photometric technique to identify your galaxy just before the second burst at redshifts of 2, 3, 4, and 5. How would you identify your galaxy just after the second burst at the same redshifts?
Problem #5. Given the star formation history you are using for your synthetic galaxy, its time to play with Starburst99 (www.stsci.edu/science/starburst99).

1. Do this part analytically (i.e. without using Starburst99). Make a plot of the supernova rate (# of SN yr\(^{-1}\)) between the second and third bursts of star formation. Yes, you will have to play around with the lifetimes of stars of different masses. Only consider Type II SN.
2. Compare what you came up with in part 1 with the results you get from Starburst99. Make sure you let me know what metallicity you picked.
3. What is the absolute magnitude of your galaxy in V, B, and K just before the second burst of star formation?
4. What is the mechanical luminosity of your galaxy as a result of the 3\(^{rd}\) burst of star formation?
5. Assuming an instantaneous burst of star formation, what is the effect on the mechanical luminosity of changing the exponent of the initial mass function?

Problem #6 – yes, this one is (sort of) from the midterm

Assume there are \(~0.05\) stars pc\(^{-3}\) in the solar neighborhood. Just to remind you, the solar neighborhood resides about 8.5 kpc from the Galactic center and sits at the midplane. Further assume that 1% of the stars in the solar neighborhood are actually halo stars. You will need to make some assumptions/guesses about the basic structure of the Galaxy.

a. What is the density of stars 500 pc above the solar neighborhood? What fraction of those are disk stars? What fraction are halo stars?

b. What is the density of stars in the midplane 20 kpc from the Galactic center? What fraction of those are halo stars?

c. What is the density of stars in the midplane 2 kpc from the Galactic center?

d. How would your estimate in part (a) change if the Sun’s distance to the Galactic center was actually 7 kpc instead of 8.5 kpc. Assume everything else remained the same.

e. If the mass-to-light ratio in the disk is 2 M\(_\odot\)/L\(_0\) what V\(_z\) would you measure for the disk stars you identified in part (a)?

f. What V\(_z\) would you measure for the halo stars you identified in part (a)? How does this number (V\(_z\) for halo stars) depend on the mass-to-light ratio in the disk?

g. Now assume you are looking at stars 3 kpc above the solar neighborhood. What fraction would you expect to be halo stars? Assume half of the halo stars actually belonged to a stellar stream associated with a dwarf galaxy which can be modeled as being on a circular orbit of radius 9 kpc and moving towards the plane. Make a sketch of the distribution of v\(_z\) you would expect for the entire halo population (halo + stellar stream stars). The axes should be number vs v\(_z\).
Problem #7

Go to the Sloan Digital Sky survey (http://cas.sdss.org/dr3/en/tools/places) and check out the clusters Abell 0957 and ZwCk 1719 (Abell 2255). If you click on the image you will get an analysis page that will provide you with all sorts of information once you click on an object. Make sure you zoom out enough to get a good look at the cluster. Click on about 20 galaxies and see if you can measure the velocity dispersion similar to the one you did in the “Clusters” lab. Part of the point is to show you that this isn’t easy!