Problem 1 (10 points).
   a) Calculate how hot the interior of the Earth would have been if all of the heat of accretion had been retained. Do the same for Venus, Mars, and Pluto. Briefly compare and contrast your answers. Explicitly state whatever assumptions you make.
   b) Was there enough energy to completely melt the proto-Earth?

Problem 2 (25 points). Here’s how to build a planet.

1. Evaluate the moment of inertia, $I$, of a uniform density spherical planet of radius $R$ about its spin axis by integrating the expression $dI=r^2 dm$ over the volume of the sphere. Write your answer in terms of $R$ and $\rho$ and in terms of $R$ and $M$.
2. Will the moment of inertia increase or decrease for an oblate planet? What about for a differentiated planet with a dense core and a less dense mantle? Explain your answers.
3. Use your answer from part 1 to get the moment of inertia of a two-layer planet with a core of radius, $R_c$, and density, $\rho_c$, and a mantle of radius, $R$, and density, $\rho_m$. Write your answer in terms of the radii and densities. Apply your result to get a constraint on the interior structure of Mars using the measured $I_{\text{Mars}} = 0.365MR^2$. Write the constraint in terms of $R_c$, $R$, $\rho_c$, $\rho_m$, and $\rho_{\text{ave}}$ ($=3.93$ g cm$^{-3}$).
4. Write down an expression for the total mass of the planet in terms of $R$, $R_c$, $\rho_m$, $\rho_c$. Eliminate mass in favor of $\rho_{\text{ave}}$ to get a second constraint on the interior structure of Mars.
5. Parts 3 and 4 give two constraints on the three unknowns $R_c$, $\rho_c$, $\rho_m$. If we assume a core density for Mars, the system reduces to two equations in two unknowns. Eliminate the core radius from your two equations to get a single equation that relates the two unknown densities. Assume a Fe core with $\rho_c = 7.5$ g cm$^{-3}$, and guess different values of $\rho_m$ until you find a solution (this equation cannot be solved analytically). What core radius, $R_c$, does your answer suggest?

Problem 3. (15 points) A 100 km diameter target asteroid is impacted by a projectile that has a velocity of 10 km s$^{-1}$. Assuming the projectile has the same mean density as the asteroid, what size must the projectile be in order to totally explode the asteroid assuming gravity is the only force binding the asteroid together? What size projectile (assuming the mean density of an asteroid) would it take to totally explode a 10,000 km (Earth-size) body at the same velocity?

Problem 4. (20 points) Let’s play with some craters. The Venus Crater Database (http://astrogeology.usgs.gov/Projects/VenusImpactCraters/venus_download.html) contains valuable information about the sizes of identified craters on our sister planet. In fact, you can download the entire list of impact craters as an Excel spreadsheet.

1. Plot the size distribution of Venusian impact craters (number of craters of a given size). Discuss your plot. Are there any cutoffs at large or small crater sizes? Is it a smooth function? Is it what you expected?
2. Try to fit an “easy” mathematical expression (e.g. power law, Gaussian) to this distribution. If you can’t, that’s ok, but you need to explain why the distribution can’t be fit so easily. If you can fit it with an “easy” mathematical expression, what is that expression? What do you think the implications of that expression are?
3. The rule of thumb for the Earth is that the crater is roughly ten times the size of the impactor. Estimate what the rule of thumb would be for Venus and plot the estimated size distribution of impactors.

Problem 5. (20 points) Explore Mars. Go to http://www.msss.com/mars_images/moc/moc_atlas/. You can get there via the NASA page
a) Find some region that contains what you consider to be evidence that liquid water once flowed on the Martian surface. Note the coordinates and write a few sentences about why you think it shows evidence of running water.

b) Pick an equatorial region and zoom in until you have a good view of a region that is 5 degrees on a side. Measure the crater density for your region (number of craters of a given size per square kilometer).

c) Using your crater density and the figures from lecture, estimate the age of your region.

Using your crater density, show a plot of the size distribution of impactors. How does this plot compare with the one you got in part 3 of Problem 4.

**Problem 6. (10 points)** Show that the maximum height of mountains on Mars should be 2-3 times higher than that on the Earth.