PTYS 411 - Geology and Geophysics of the Solar System
Homework #4 – Assigned 3/27, due 4/10

---

1) *Mercury's thrust faults.* As Mercury's core solidifies it contracts. If the core volume decreases by a factor F, then show that the surface area of the planet decreases by a factor:

$$1 - \frac{2(1-F)}{3}\left(\frac{R_c}{R_P}\right)^3$$

Assume F is 0.995, how many square kilometers did Mercury loose?

Mercury's lithosphere broke along many thrust faults during this episode. If each fault is about 500km long and has a displacement of 2km, how many faults does Mercury need to accommodate this shrinkage?

Assume a thrust fault dip of 45°.

This system of global thrust faults is unique to Mercury, yet the other terrestrial planets also possess cooling cores. Why don't we see this happen on the Earth, Venus or Mars? The answer is different for each body.

2) *Impacts on Mars and Venus*: The dense atmosphere on Venus effectively screens out many impacting bodies. A projectile at velocity v experiences a ram-pressure from the atmosphere, if this pressure exceeds the strength of the material then the projectile fragments. The ram pressure is the product of the amount of atmospheric material scooped up by the projectile and the momentum of that material per unit area. Show that it equals:

$$P_{ram} \approx v^2 \rho_{atmosphere}$$

where $\rho_{atmosphere}$ is the atmospheric density. The hydrostatic equation gives the pressure variation with height as:

$$P(z) \approx P_S\, e^{-z/H} \quad where \quad H = kT/g\mu_{ATM}$$

where P_s is the surface pressure, k is Boltzmann's constant and μ_{ATM} is the molecular weight of the atmospheric particles.

Convert the atmospheric pressure equation to density. What is the atmospheric surface density and scale height for Venus, Earth and Mars. Use temperatures of 750, 270 and 200K and surface pressures of 100, 1, 0.01 bars respectively (1 bar ~ 10^5 Pa).

If a projectile barely makes it to the surface without fragmentation on Mars, at what altitude will it break up if it had hit Venus. Assume the lowest possible impact speed in both cases.

One way to recognize meteors is by their fusion crust i.e. the exterior if the rock is melted during its passage through the atmosphere. How hot do the gases at the leading edge of the meteor get, just before impact into the martian surface? (assume the atmospheric gas is adiabatically compressed to the ram pressure). Is this hot enough to melt rock? How deep does this thermal disturbance penetrate into the meteorite?

Note: Adiabatic compression means that gas is compressed too fast to loose energy and its temperature rises. For adiabatic compression of an ideal gas: $T\,P^{\frac{1-\gamma}{\gamma}}$ equals a constant, where γ is the ratio of specific heats (~7/5) for air.

3) *Oceanic lithosphere subduction on Earth.* Oceanic plates are formed at spreading ridges with essentially zero thickness; they thicken progressively as they move from the ridge to the subduction zone. As they're thickening by freezing mantle material to their bases, they become cooler, denser and subside.

Let's say that, at some distance from the spreading ridge, the lithosphere is 100km thick and the seafloor has subsided by 3km. Assuming the uncooled mantle has a density of 3300 Kg m^{-3} and that the plate is isostatically supported everywhere, is this plate ready to be subducted? [C*alculate the density difference between the slab and the mantle. Don't forget this is happening underwater*].

4) Sand dunes on Triton? (From Chap 9 of Melosh 2011)
Triton, Neptune's largest moon, possesses a very thin atmosphere that is composed mainly of N_2 gas at a chilly 38 K. Nevertheless, geysers spout plumes 8 km high into the atmosphere. Suppose that loose "sand" grains of ice (perhaps from impact ejecta) lie on the surface. How fast do the winds of Triton have to blow to just entrain such ice grains? Compute both the minimum friction velocity needed to loft these grains and the minimum wind speed 1 meter above the surface. Compare this velocity to the speed of sound in Triton's atmosphere. What can you conclude about the probability of finding "sand" dunes on Triton when it is be visited by a spacecraft with an imaging system capable of resolving such features? Facts that you may find useful: The viscosity of nitrogen gas at 38 K is about 2.2×10^{-6} Pa-s and its density at Triton's atmospheric pressure of 1.5 Pa is 1.3×10^{-4} kg/m^3. The acceleration of gravity at the surface of Triton is 0.78 m/sec^2.