Homework 3. Flow laws and their applications to planetary tectonics. The key scaling factor among planets are (1) thermal regime, (2) lithology, (3) strain rate/stress magnitude, and (4) the presence and absence of water.

A complete form of a flow law (also known as power laws) for ductile deformation under the ***steady state*** is written in the following form:

$$|\dot{\varepsilon}_n| = Ad^{-b}\left(f_{H_2O}\right)^r\left(f_{O_2}\right)^q \exp(\alpha\emptyset)\,(\sigma^{Diff})^n \exp\,[-\frac{E+pV}{RT}]$$

where $\dot{\boldsymbol{\varepsilon}}_{\boldsymbol{n}}$ is normal strain (also known as extension), $\boldsymbol{A}$ is experimentally determined material constant, $\boldsymbol{d}$ is grain size, $\boldsymbol{f_{H_2O}}$ is fugacity of water, $\boldsymbol{f_{O_2}}$ is fugacity of oxygen, $\emptyset$ is melt fraction typically less than 0.12, $\boldsymbol{\sigma^{Diff}}$ is differential stress, $\boldsymbol{E}$ is activation energy (kJ/mol) (typically in the range of 150-450 kJ/mol), $\boldsymbol{p}$ is pressure, $\boldsymbol{V}$ is activation volume per mole, $\boldsymbol{T}$ is temperature, and $\boldsymbol{R}$ = 8.314472 [J/mol °K] is universal gas constant (or Boltzman constant); *b, r, q*, and *n* are exponents in the equation that are all positive constants varying with material, and α is a material constant that is equal to 25-30 in the lower stress regime (<20 MPa) and 30-45 in the high stress regime (> 20 MPa).

(1) Using the above equation, please write out the form of the effective viscosity as a function of the differential stress and differential strain.

(2) As strain rate for tectonic deformation may vary in planetary bodies, discuss its effect on the strength of the lithosphere on a slowly deforming planetary body such as moon and the Mercury where the strain rate may be on the order of $\dot{\varepsilon}_n = 10^{-18}$ in comparison to $\dot{\varepsilon}_n = 10^{-14}$ to on 10^{-15} Earth.

(3) Assume that (1) Mercury and Moon have the same size and same composition, (2) the thermal gradient of Mercury in the lithosphere is twice higher than that on the Moon, and (3) the strain rate of Mercury is two orders of magnitude higher than that of the Moon, what is the relative lithospheric strength between Moon and Mercury assuming that the thickness of the lithosphere on both planetary bodies is defined by the same isotherm (on Earth, this temperature is usually taken as 1350 °C?