

PROBLEM SET 1: STRESSES IN THE EARTH

EAS 4312/6312: Geodynamics

Assigned: 09/04/13

Due: 09/11/13

NAME: _____

OTHERS CONSULTED: _____

A note about your homework: Please be neat and organized! Once you have found a way to the answer, please rewrite it in an orderly fashion so that others can follow your steps, and put a box around your final solution, when appropriate. Include this page as the cover, show all of your work, and list all who helped with this set, including your instructor. *An answer with incorrect or absent units will be considered wrong!*

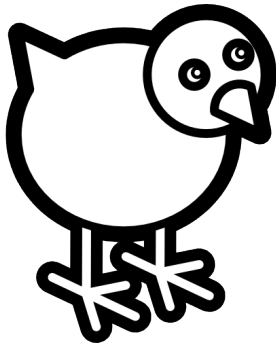


Figure 1: Consider a spherical chicken. Source: colouring-book.org

Mathematic Approximation

1. Frequently, in Earth Science research we must make calculations based on physical properties that are either not precisely known or are very difficult to directly measure. This, of course, requires us to make scientifically justifiable approximations that will allow us to get closer to understanding the forces behind the processes. Often times Earth Scientists, particularly Geophysicists are delighted to get within an order of magnitude. Such is the case in the title example of the book *Consider a Spherical Cow* by J. Harte.

- (a) To illustrate this example, estimate the approximate mass of a chicken, if we simply assume it to be a single sphere, of reasonable radius, and having a reasonable plucked density.
- (b) Then, assuming the resultant chicken meat is 10x more nutritious than the equal mass of vegetable matter and that the

chicken is 10% efficient at turning grain nutrition to muscle, how much grain would that chicken eat over its growing life?

Isostasy

2. Consider the Laurentide ice sheet that was, at the last glacial maximum (LGM; $\sim 20\text{Ka}$) on average 2 km thick in its center. Starting with your own diagram of the problem, calculate the expected deflection of the crust if the ice sheet was in place long enough to be in isostatic equilibrium. Assume realistic densities of the ice and mantle. Note that the answer is independent of what you assume for the density of the crust.
3. Determine the tectonic stress in the continent for the oceanic-continental structure in the below figure by proceeding as follows:
 - (a) Derive the equation for the net difference in the lithostatic pressure force (tectonic force), F_T , between the continental and the oceanic crust by integrating the pressures over a depth equal to the thickness of the continental crust, h_{cc} .

- (b) Now, using reasonable approximations for each of the other parameters, determine h_{cc} .
- (c) Finally, calculate the average tectonic stress across the boundary equal to h_{cc} .

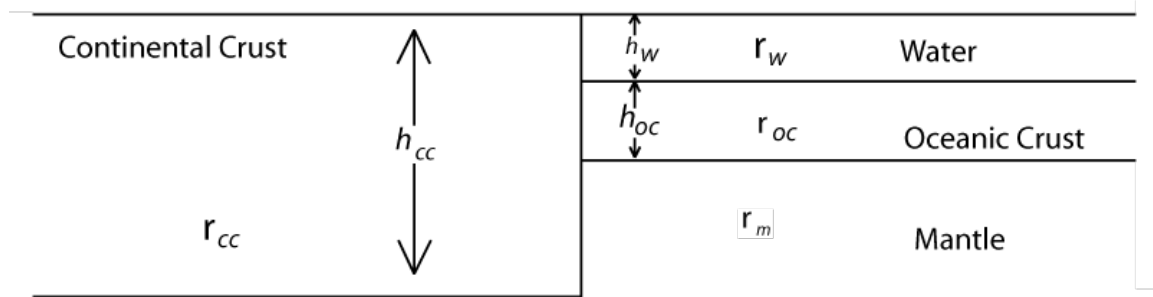


Figure 2: A fair representation of the passive margin of the east coast of the United States.

Stress and Friction

- Consider a block of vesicular basalt that is 3 m long in each x , y , and z directions. The block is sitting on a rough horizontal surface (on the z -plane) with a coefficient of friction, $f=0.4$. Assuming 10% porosity, use an appropriate density, ρ , to answer the following:
 - What is the normal stress on the rough surface?
 - What is the shear stress necessary to overcome gravity and friction?
 - What is the associated shear force necessary to move the block?
- In-situ stress measurements: An over-coring stress measurement in a diamond mine at a depth of 2 km gives normal stresses of 62 MPa in the N-S direction, 48 MPa in the E-W, and 51 MPa in the NW-SE direction.
 - Determine the magnitudes and directions of the principle stresses.
 - What are the average two-dimensional (2D) normal stresses, and the deviatoric principle stresses?
 - How does this deviate from the lithostatic load?

Additional Problems for Graduate Section

- As a first-order approximation, the Earth is made up of 2 compositionally distinct layers (the mantle and core).
 - Derive the set of equations that describe, as a function of radius r , the gravitational acceleration $g(r)$.
 - Do the same thing for pressure $P(r)$.
 - Finally, assume reasonably realistic average values for the densities of the mantle and core, as well as the radius of the Earth and outer core. Use this information to plot these functions on a single graph. Be sure to label all axes as well as create an appropriate legend labeling the functions.