ES.103 – PROBLEM SHEET 7

***Problem 7 .1***

A volcanic plug of diameter 10km has a gravity anomaly of 0.3 mm/s$^2$. Estimate the depth of the plug assuming it can be modelled by a vertical cylinder whose top is at the surface. Assume the plug has a density of 3000 kg/m$^3$ and the rock it intrudes has a density of 2800 kg/m$^3$.

***Problem 7 .2***

A sedimentary basin is formed on the sea floor and isostatic compensation is achieved by the displacement of mantle material $\rho_m$. Show that the sediment thickness $s$ is related to water depth $d$ by

$$s = \left( \frac{\rho_m - \rho_w}{\rho_m - \rho_s} \right) (D - d)$$

where $D$ is the initial depth of the sediment free ocean, $\rho_w$ is the density of water and $\rho_s$ is the sediment density.

What is the geoid anomaly associated with the sediment basin if the sediment thickness is 1 km, the final water depth, $d$, is 3 km, $\rho_s = 2500\,\mathrm{kg\,m^{-3}}$ , $\rho_m = 3300\,\mathrm{kg\,m^{-3}}$ , $\rho_w = 1000\,\mathrm{kg\,m^{-3}}$ , $g = 10\,\mathrm{m\,s^{-2}}$, and $G = 6.673 \times 10^{-11}\,\mathrm{m^3\,kg^{-1}\,s^{-2}}$.(You may ignore the contribution of the oceanic crust).

Do you think this geoid anomaly would be observable?

***Problem 7 .3***

a) Define the term ”Pyrolite”
b) Which is denser, silicate perovskite or olivine? – justify your answer
c) What is ”Gruneisen’s ratio” and why is it useful?
d) What is the ”Peclet number” and what is its value for the mantle? Make a guess for what it might be in the core??

***Problem 7 .4*** Graph $g$, the acceleration due to gravity, as a function of radius in the Moon assuming it has a constant density, $\overline{\rho}$ , of $3350\,\mathrm{kg\,m^{-3}}$ and a radius, $R$, of 1738 km? Graph the pressure as a function of radius. A multi-anvil press can now reproduce the conditions at a depth of 700 km inside the Earth; could this apparatus reproduce conditions at the center of the Moon?

***Problem 7 .5*** The temperature distribution in the lower mantle is thought to be adiabatic and its variation with density is given by

$$\frac{dT}{d\rho} = \frac{T\gamma}{\rho}$$

$\gamma$ is Grüneisen’s ratio and is a weak function of density governed by the equation

$$\frac{d\gamma}{d\rho} = -\frac{\gamma}{\rho}$$

Compute the temperature at the core mantle boundary (MCB) where the density is $5500\,\mathrm{kg\,m^{-3}}$ using the following properties at the 670 km discontinuity : $\rho = 4400\,\mathrm{kg\,m^{-3}}$, $T$=1950K, $\gamma$=1.5.

Assuming there is no thermal boundary layer at the base of the mantle, what is the total power loss out of the core given that the radius of the core is 3485 km, $g_{MCB} = 10\,\mathrm{m\,s^{-2}}$, $\phi_{MCB}$ (the seismic parameter) = 120 km$^2$s$^{-2}$ and the thermal conductivity is $5\,\mathrm{W\,m^{-1}\,K^{-1}}$.

Does this value seem reasonable?

If the melting temperature of core material is greater than 2800K at the MCB can you say anything about the distribution of heat sources in the Earth from this calculation.