12.002 Physics and Chemistry of the Earth and Terrestrial Planets
Fall 2008

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Problem Set #4: Conduction and Subsidence
due Friday Oct 17 in class

Problem 1. Age of the Earth

In 1862, Lord Kelvin used the conduction equation and the heat flow from the Earth to estimate an age for the earth. Repeat Kelvin's caluculation using the present heat flow out of the Earth, about 50 mW/m^2=0.05 W/m^2, an initial temperature of 1300°C and a surface temperature of 0°C. You will also want to know the thermal conductivity (5 W/mK) and thermal diffusivity (10^{-6} m^2/s) to complete this calculation. After how many millions of years will the cooling lithosphere have a heat flow equal to the present surface heat flow through the Earth? This was how Kelvin got his estimate of the age of the Earth. Why did he get the wrong answer? (hint: see next problem)

Problem 2. Heat Loss by Plate Tectonics

The Earth's oceanic lithosphere is created along mid-ocean ridges and consumed in subduction zones. Between these two events, it cools conductively as a function of age. Suppose we have a rectangular ocean that is being created at a half-spreading uniform rate of 20 mm/yr. The oldest ocean floor is 200 m.y. old and, because of uniform creation rate, there is a linear relationship between age and distance from the spreading ridge. The ridge is 1000 km long.

a) compute the area of the (half) ocean basin.
b) compute the total heat loss (in W) through the entire half-ocean.
c) compute the total heat loss (in W) through the part of the ocean underlain by lithosphere less than 10 m.y. old.
d) compute the total heat loss (in W) through the part of the ocean underlain by lithosphere less than 50 m.y. old.
e) How does this help you to answer the last question in problem 1.

Problem 3. Subsidence and Cooling

Compute the subsidence and lithospheric thickness of subsiding oceanic lithosphere at 1, 10 and 100 Ma. Use:

thermal diffusivity: 10^{-6} m^2/s
thermal conductivity: 5 W/mK
coefficient of thermal expansion: $3.10^{-5}°C^{-1}$
initial mantle temperature: 1300°C
and define the base of the lithosphere as 1290°C.