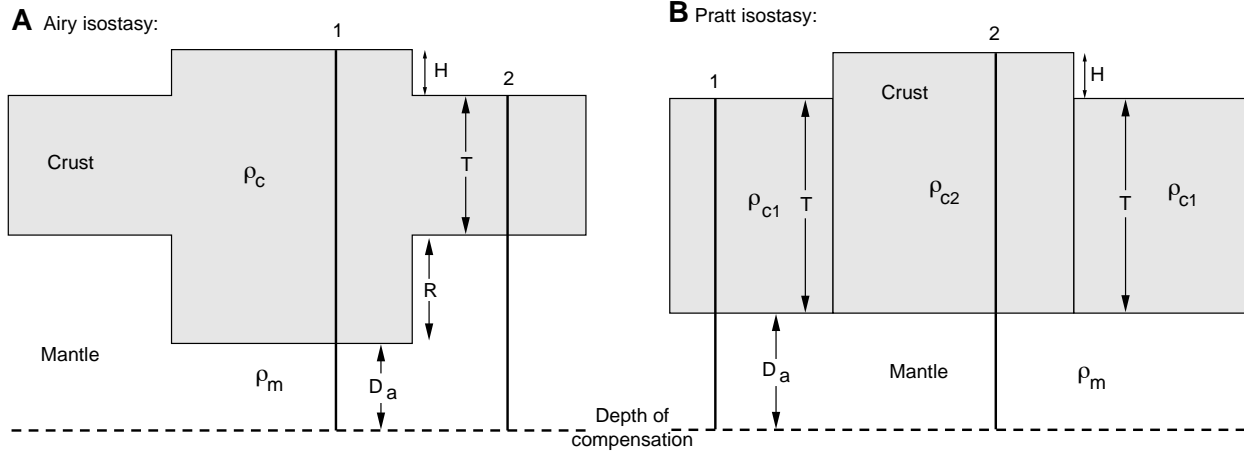


Orogenesis and Isostasy

Exercise

CALCULATING ISOSTATIC SUPPORT OF MOUNTAINS

Isostasy is based upon **Archimedes principle**—that the weight of a floating solid is supported by the weight of the fluid that it displaces. Archimedes was the ancient Greek scientist who is said to have made his insights about fluid displacements getting into the bathtub. The reason that an iceberg with a mass of 100,000 kg does not sink to the bottom of the ocean is that it displaces exactly 100,000 kg of water. The reason that nine-tenths of the iceberg is below the waterline is that ice is only nine-tenths as dense as water—100,000 kg of water are displaced by 90,000 kg of ice, and the remaining 10,000 kg of the iceberg stand above the surface.



The calculation of isostatic support is based upon the principle that at any given depth within a fluid, called the **depth of compensation**, the pressures generated by overlying material are everywhere equal (see Figure 1). This means that the weights of any two columns of material, measured down to the depth of compensation, are equal. Given an area of uniform crustal density (ρ_c) and thickness (T), a mountain block with elevation H above the surface, and an arbitrary distance down to the depth of compensation (D_a), we can calculate the mountain-root depth (R) beneath the base of the crust for Airy isostasy (Figure 1A). Weight (W) equals mass (volume \times density) times gravity (g). For column 1, through the mountain block

$$W_1 = (H\rho_c + T\rho_c + R\rho_c + D\rho_m) g \quad (1)$$

The weight of column 2 equals

$$W_2 = (T\rho_c + R\rho_m + D\rho_m) g \quad (2)$$

The weights of the two columns equal each other, therefore

$$W_1 = W_2 \quad (3)$$

$$(H\rho_c + T\rho_c + R\rho_c + D\rho_m)g = (T\rho_c + R\rho_m + D\rho_m)g \quad (4)$$

$$H\rho_c + T\rho_c + R\rho_c + D\rho_m = T\rho_c + R\rho_m + D\rho_m \quad (5)$$

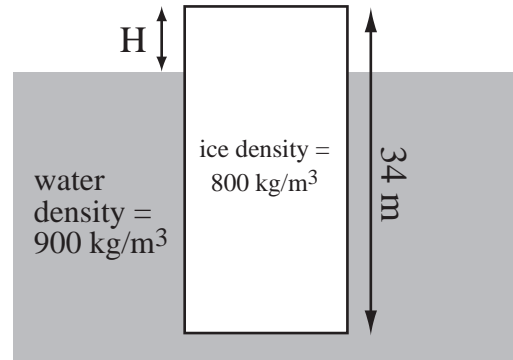
$$H\rho_c + T\rho_c + R\rho_c = T\rho_c + R\rho_m \quad (6)$$

$$H\rho_c + R\rho_c = R\rho_m \quad (7)$$

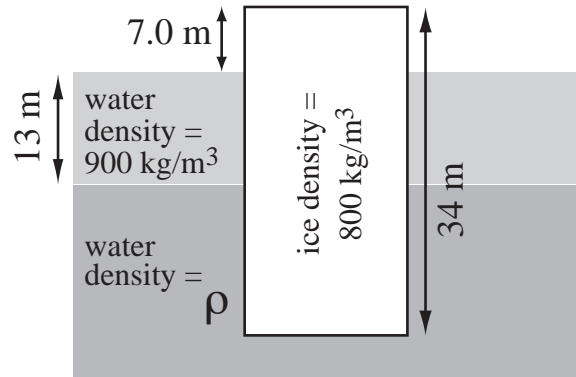
$$R\rho_m - R\rho_c = H\rho_c \quad (8)$$

$$R = H\rho_c / (\rho_m - \rho_c) \quad (9)$$

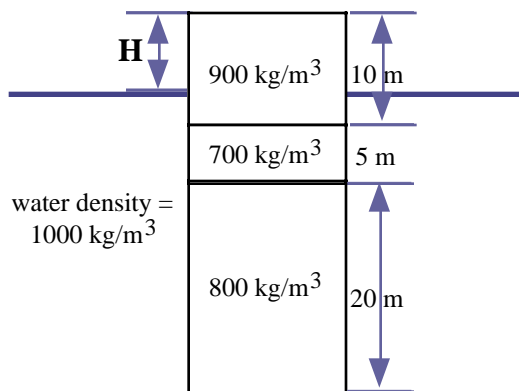
- 1) An iceberg is floating in the ocean as illustrated to the right. Use the information provided to calculate the height that the iceberg stands above the water line.



- 2) A simple iceberg is floating in water separated by a thermocline, which results in a density difference. Use the information shown to find the density of the water beneath the thermocline (ρ).



- 3) A **stratified** iceberg is floating in the ocean as illustrated below. Use the strata thicknesses and the densities shown to calculate **H**, which is the height of the iceberg above the water.



- 4) The Tibetan Plateau is the largest mountain mass on Earth. Most of the Plateau -- an area larger than France -- stands at 5000 m in elevation or higher! Equation (9) be easily solved to give the depth of the crustal root beneath the Tibetan Plateau, which has an average elevation of 5000 m. We know that the density of continental crust is about 2700 kg/m^3 , the density of the mantle is about 3300 kg/m^3 , and the average thickness of the crust here is 40 km. What would be the thickness of the root (R) beneath the Tibetan Plateau if you assume perfect Airy isostasy?

- 5) What would be the density of the crustal root (ρ_{c2}) if you assume perfect Pratt isostasy?