PHYS 3511, Biological Physics, Assignment 6

Due Friday March 24. Read Philip Nelson's Biological Physics: Section 7.2 Osmotic Pressure; Section 7.3 Osmotic Flow

QUESTION 1 **Problem 7.1 from Philip Nelson's Biological physics**

QUESTION 2 **Problem 7.3 from Philip Nelson's Biological physics**

QUESTION 3 **Deep Sea Fish:** A fish in the ocean has volume, $V_{fish} = 4\times10^{-3} m^3$ and density $\rho_{fish} = 1060 kg \bullet m^{-3}$. It has a separate air sac of unknown volume, V_{sac}. Suppose it swims at a depth of h = 1000m. Due to **Archimedes Principle**, it floats due to an **upward buoyant force**, $F_B = \rho_{sea}\left(V_{fish} + V_{sac}\right)g$, which cancels its weight.

A) The fish is floating motionless at h = 1000m. Calculate its mass $M = \rho_{fish}V_{fish}$, and draw a free-body-diagram of all forces acting on it. Using newton's first law, and $\rho_{sea} = 1032.85 kg \bullet m^{-3}$, find V_{sac}.

B) The pressure on the fish at this depth is $P = P_{atm} + \rho_w gh$, where $P_{atm} = 1.01325\times10^5 Pa$ and for simplicity us $\rho_w = 1000 kg \bullet m^{-3}$. Use the ideal gas law, $PV_{sac} = nRT$ (T = 273.15 K) to estimate the number of moles of gas molecules in the air sac.

C) The fish is suddenly brought to near the surface (say at $h = 0.5m$) where $\rho_{sea} = 1028.1 kg \bullet m^{-3}$. Calculate the volume of the air sac, V_{sac}. Hence calculate the Net vertical Force, F_y^{Net} acting on it. What will happen to the fish?

QUESTION 4 **Cell lysis of blood cell**. If we put pure water on both sides of a membrane where one side has a pressure drop of Δp, the volume flux out of the high-pressure side is $j_v = L_p\Delta p$, where L_p is the filtration coefficient. For this question assume $L_p = 7\times10^{-6} cm \bullet s^{-1} \bullet atm^{-1}$. Consider "spherical" red blood cell of area $140\mu m^2$ that will lyse (rupture) if its area expands by 2%. Assume that initially the **osmotic pressures** due to various **osmolytes** (naturally occurring organic molecules) inside and outside are equal $P_{in} = P_{out} = 3.8kPa$ so that $\Delta p = 0$, and there is no net flow of water into or out of the cell. Suppose that the blood cell is exposed to a hypotonic environment, where the osmolyte concentration is decreased by 10%, in which case water will flow into the cell. Calculate how long it will take for the cell to lyse. **HINT:** 1) use temperature $37^\circ C$; 2) total flow is $\Delta V = j_V At$; 3) assume that the blood cell is a sphere, even though, in reality, it is not; 4) sphere volume $V = \left(4/3\right)\pi r^3$, surface area $S = 4\pi r^2$; 5) find initial radius r_i for $S_i = 140\mu m^2$, then find final radius r_f when area increase by 2%, $S_f = 1.1S_i$; 6) Find change in volume for cell lyse $\Delta V = V_f - V_i$; 6) Use $\Delta V = j_V At$ to find time.