**ABE 30800**

**Examples Unsteady State and Convections Mass Transfer**

**Problem 1**

1. Banana slices of 5mm thickness and 25mm diameter have to be dried:

(a)Provide reasons as to why the moisture transport can be considered one-dimensional.

(b)Initial average moisture content of the banana slices is 3 kg/kg dry matter and their final moisture content upon the end of the drying process is 0.20 kg/kg dry matter. The equilibrium moisture in the banana slices corresponding to the moisture and temperature of the air in contact with the surface of the slices is 0.18 kg water/kg dry matter. Diffusivity of water in banana is estimated as 1.2x10-10 m2/s and assumed constant. Derive the equation(s) to estimate and calculate the time necessary to achieve the desired drying; what is that value?

(c)As the banana slices losses moisture they shrinks and it has been observed that the thickness is reduced by 60% in the overall drying process. It is possible by developing a model to estimate the drying of the banana slices whiles shrinking of the slices occurs. However, such a model is involved and requires the use of a numerical method. Instead, you can calculate, as an extreme, what will be the drying time if the thickness of the slices is reduced by 60%. For this case, calculate that drying time. How this calculated drying time would compare with that calculated in (b) and how with the the drying time that would be calculated using the numerical method that assumes shrinkage of the slices during the drying process. For the later, you can only do a qualitative comparison.

**Problem 2**

DNA hydrogels are being investigated as a protein drug delivery system but unfortunately little information about their properties exists, specifically on how a drug can diffuse through these gels. In order to assess the diffusion of a drug in these gels an experiment was performed using a DNA gel and the protein Bovine Serum Albumin (BSA). The gel was prepared having slab geometry and containing BSA initially uniformly distributed in the gel. To estimate the diffusion of BSA though the gel the BSA loaded gel was put in contact with pure water (i.e. containing no protein) and the amount of BSA diffusing in the water measured. In the experiment the amount of BSA released to the water was measured after 1 day and 3 days and was 4.15 and 6.25 grams, respectively.

1. Provide an equation from which you can calculate the diffusivity of BSA in the DNA gel. Start from the initial equation and show all the steps employed to have the final equation, including showing necessary integrations. No numerical calculations are asked for this question; instead you need to write the starting equation and the final equation to be used to solve the problem. Also write all the assumptions used to reach the final equation(s) to solve the problem.

**Hint 1**: Since the BSA released in the water is measured as a weight of BSA, you can calculate the weight inside the gel as *Mavg(t) cavg(t)V*, where *cavg(t)* is the average concentration of BSA in the gel at a time *t* and *V* is the volume of the gel. The amount of BSA released is *Mr(t)=Mi – Mavg(t),* where *Mr(t)*, *Mi*, and *Mavg(t)* are the amount of BSA released, the initial amount of BSA in the gel and the average weight of BSA at a time *t*.

1. Estimate the diffusivity of BSA in the DNA gel if the gel thickness is 6mm, and all the other dimensions are large enough to assume diffusion only in a direction.

**Hint 2**: The estimation of the diffusion coefficient may require the solution of a non-linear equation (a cubic equation) – use what you learnt in ABE 301 or ABE 303 to solve this equation and get the diffusion coefficient *D*. One of the numerical you learnt was the Newton-Raphson method that can be implemented in MathCad, Matlab or Excel, use the software with which you feel more comfortable, that should not change the final answer.

**Problem 3. Diffusion through a stagnant gas**

The water surface, in an open cylindrical tank is 7.5 meter below the top. Dry air is blown over the top of the tank and the entire system is maintained at 18oC and 1 atm total pressure. If the air in the tank is stagnant, determine the rate of water loss through the top in g*/*m2·s. The diffusivity of water vapor through air at this temperature is 2*.*77×10−5m2*/*s. The diameter of the tank is 2 m.

**Problem 4**. **Ocular evaporative water loss in lizards**

Reptiles are often able to successfully colonize arid habitats because their bodies have a very low rate of evaporative water loss (EWL). Although a reptile’s outer covering is virtually impermeable to water, the wet ocular surfaces freely evaporate water to the environment. While the eye area comprises less than 0.03% of the lizard’s total surface area, the water loss from these moist surfaces can be very significant.

By considering the data below for a lizard habitat:

(a) Write the equation for mass transfer coefficient assuming air flow over the eye as laminar flow over a flat plate.

(b) For a wind velocity that leads to an average heat transfer coefficient of 11 W/m2·K, calculate the average mass transfer coefficient for air flow over the eye.

(c) Find the rate of evaporative water loss (EWL) from the eye.

(d) If the total evaporative water loss (total EWL) from the eye and the body surface is 1.77 mg/h, find the EWL from the eye as a percentage of total EWL.

Assume that the surrounding air is completely dry. Percentage of time the eyes are open is 60%. The total surface area of both eyes combined is 8.5 × 10−7m2, diffusivity of vapor in air is 2.6 × 10−5m2/s, vapor concentration in the air at the eye surface corresponds to the vapor pressure of water at the lizard’s surface temperature of 37oC, thermal conductivity of air is 0.027 W/m·K, density of air is 1.14 kg/m3 and specific heat of air is 1 kJ/kg ·K.

**Example 5**. **Evaporation from a falling drop of water**

Calculate the instantaneous rate of evaporation per unit surface area from a falling drop of water in dry air at an average temperature of 35oC at the instant when the diameter is 1mm. Diffusivity of water vapor in air at 35oC is 0.273 × 10−4 m2/s, instantaneous velocity of drop is 3 m/s, vapor pressure of water at 35oC is 5.62 × 103 Pa. Air properties can be found in Appendix C.8.