**Practice Problem Set 1 (NSP)**

1. In a CFUF system at the steady state, the film theory is valid. The real retention is 0.5<Rr<0.8. Depending on the turbulence in the flow channel, vw/k is (i) 1; (ii) 0.5 and (iii) 2. Find the bounds on observed retention in three cases separately.
2. Seawater is desalinated by reverse osmosis in a flat sheet rectangular membrane cell of half height 2 mm. Feed concentration of salt (NaCl) is 30 kg/m3. Assume osmotic pressure model under film theory assumption and at steady state. Osmotic pressure is given as , where, is in Pa and *c* is in kg/m3. Permeation of salt through the membrane is governed by solution diffusion model given as, where, *vw* is permeate flux, cm and cp are solute concentration on membrane surface and in permeate; B=10-6kg/m2.s. Membrane permeability, Lp=8x10-12 m/Pa.s. Transmembrane pressure drop, Pa. Diffusivity of NaCl in water is 1.5x10-9 m2/s. Solution density and viscosity are same as those of water. Flow inside the channel is turbulent and Sherwood number relation is . Average cross sectional velocity inside the channel is 1.5 m/s.

Find the (i) permeate flux; (ii) observed and real rejection of salt.

1. A steady state cross flow filtration occurs in a rectangular channel and consider stagnant film theory. The solute diffusivity in the mass transfer boundary layer varies as D=D0(1+k1C). The feed concentration is C0, permeate flux vw and mass transfer coefficient k (defined as the ratio of D0 and thickness of boundary layer). Derive an expression of permeate flux in terms of above quantities, observed retention (R0) and real retention (Rr).
2. For a steady state nanofiltration system, the filtration is osmotic pressure controlled and the permeation through the membrane is governed by the solution diffusion model. In such system, the real retention is not constant. Prove that (i) the real retention tends to 1 for transmembrane pressure drop much higher than the osmotic pressure difference across the membrane (); (ii) real retention tends to zero when transmembrane pressure drop is comparable to osmotic pressure difference (). (iii) Show a realistic curve (line drawing by hand) how Rr varies with and prove mathematically that there is no inflection point on this curve. Please use the usual notations for different quantities.

**R, CR**

**F, C0**

**P, Cp**

Consider an osmotic pressure controlled UF system as shown above. The cross flow system is assumed as a perfectly CSTR, i.e., the solute concentration in the flow channel is same as that at the retentate. Assume density of each stream is 1000 kg/m3. The permeate recovery with respect to feed is 40%. The feed concentration of solute is 10 kg/m3. Mass transfer coefficient inside the channel is 10-6 m/s. Osmotic pressure is given as , where, is in Pa and *c* is in kg/m3. Membrane permeability, Lp=10-11 m/Pa.s. Transmembrane pressure drop, Pa. Find the membrane area required so that the solute concentration in permeate is 2 kg/m3, if the feed flow rate is 100 kg/h.

1. In a steady state NF process, the transmembrane pressure drop is , membrane permeability, Lp, solute permeability through the membrane is B. The solute flux through the membrane is governed by the solution diffusion model. The transmembrane pressure difference is sufficiently high so that the osmotic pressure difference across the membrane is negligible. The mass transfer coefficient in the channel is k. The solute concentration in feed is C0.
2. Find the optimum transmembrane pressure drop and at this condition, the optimum permeate flux (Vw), optimum permeate concentration (Cp), optimum membrane surface concentration (Cm).

If B=K/5, find the value of observed and real retention.