These problems* introduce the kinds of questions we can solve with pen and paper glaciology. Here, unless otherwise specified, you may assume Nye-Glen flow with $n = 3$ and $A = 3.6 \times 10^{-16}$ Pa^{-3}year^{-1}.

Problem 1. A wide, parallel-sided slab of ice rests on a slope (sin α= 0.1) and has a thickness of h = 100 m. We will assume the x coordinate points along flow and the z coordinate points upward, with no gradients in y.

(a) Calculate the shear stress and normal stress at the base of the ice sheet.

(b) Outline an appropriate approximation (from van der Veen Ch. 4) for this case and find the ice surface velocity at the center of the slab.

Problem 2. Whillans Ice Stream in Antarctica has a thickness of $H = 1000$ m and a very low surface slope α that produces a gravitational driving stress $\rho g H \sin\alpha \sim 20$ kPa. The width is about 30 km. The mean temperature through the thickness is about -15°C. The ice stream is thought to sit on weak sediments that provide essentially no resistance to flow.

(a) Calculate the shear stress acting at the margins that is required for force balance.

(b) Outline an appropriate approximation (from van der Veen Ch. 4) for this case and find the ice surface velocity at the center of the ice stream. Here, you may use $A = 2.1 \times 10^{-25}$ Pa^{-3}s^{-1} for ice at -15°C†.

(c) Now, assume a small basal drag of 10 kPa, and re-compute the surface velocity.

(d) Compare your answers in parts (b) and (c) with the observed centerline velocity of 0.5km year^{-1}. Which is closer to the true value?

Problem 3. (a) Calculate the difference between the ice velocity at the surface and at the bed in a glacier 300 m thick with a surface slope of sin α =0.046. Describe other necessary assumptions.

(b) Suppose the glacier is 1000 m thick instead. How do your results change?

*Collected from a set written by Ginny Catania at UT Austin

†Table 3.4, Cuffey & Paterson