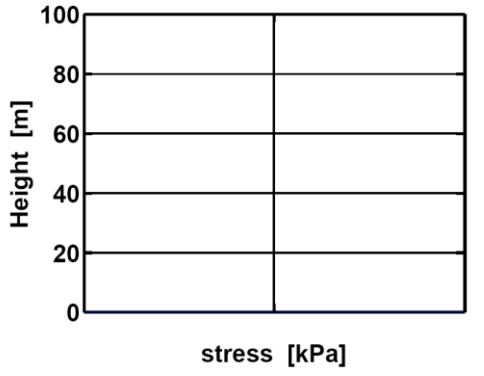
EARTH AND SPACE SCIENCE **Autumn 2017**
431 *PRINCIPLES OF GLACIOLOGY* 4 Credits, SLN 14841
505 *THE CRYOSPHERE* 4 Credits, SLN 14862

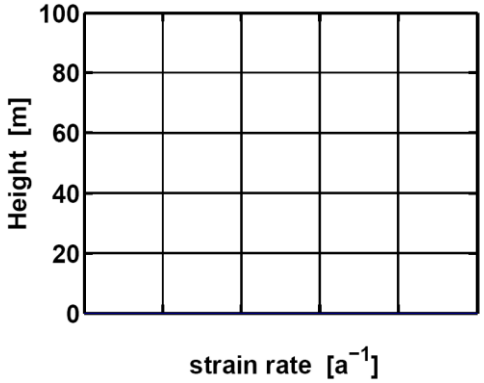
Lab Week 4 – Glacier Flow

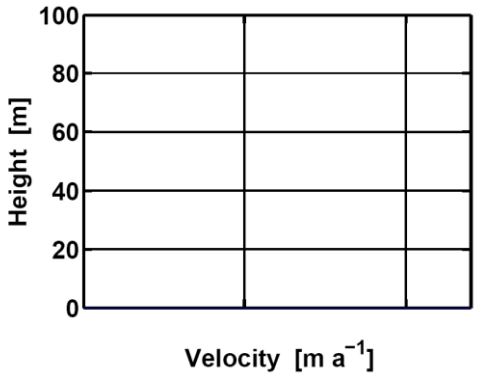
Find 1 or 2 partners, and work together to answer 1 of the following 2 questions. You and your partners will be asked to report your results to the class before the end of lab.

(1) Dynamic ice-flow estimation
A temperate glacier is 100 meters thick, with a slope of 6.3º (0.11 radian). The glacier is not sliding. Your coordinate system has *x* along the flow direction, and z is vertical, with values increasing up from the bed. The corresponding velocity components are *u* and *w*.

- Estimate the bed-parallel shear stress $\sigma_{xz}(z)$ at the bed (z=0), at 20 m, 40 m, 60 m, 80 m above the bed, and at the surface (z=100 m). Plot your results on the provided axes.
- Using Glen's flow law for ice at 0ºC, estimate the shear strain rate ($\partial u/\partial z$) at the same 6 depths. Plot your results on the provided axes.
- Estimate how fast the ice might be moving at each depth by populating the table on the following page. (Point of note: we are not asking you to use the analytic solution for ice velocity provided in class. You are approximating a solution to $\int_0^H \frac{\partial u}{\partial z}\partial z$ by computing $\frac{\partial u}{\partial z}$ at a variety of depths, and summing the computed values). Plot your results.







	ESS 431 Principles of Glaciology				Glacier Flow WORKSHEET			
	Height	Depth	Shear stress	Strain rate	Interval average	Depth interval	Velocity Increase	Velocity
	z	$(h\text{-}z)$	$\sigma_{xz}(z)$	$\partial u/\partial z$	$\partial u/\partial z$	Δz	Δu	$u(z)$
	(m)	(m)	(Pa)	(a^{-1})	(a^{-1})	(m)	(m a^{-1})	(m a^{-1})
	100							
	80							
	60							
	40							
	20							
	0							
		z = height above bed						
		h = ice thickness						
		$\sigma_{xz}(z)$ = bed-parallel shear stress at height z						
		$\tau_b = \sigma_{xz}(0)$ = basal shear stress						
		$\partial u/\partial z$ = shear strain rate						
		Δz = depth interval between calculation points						
		$u(z)$ = bed-parallel velocity at height z						

(2) Kinematic ice-flow estimation

A steady-state glacier has a net balance rate of 0.5 m a^{-1} (ice-equivalent) in the accumulation area upstream from a target cross-section, 1 km from the headwall. At this cross-section, the glacier happens to be 200 m across, and 100 m deep.

- Find the total volumetric ice flux through this cross-section for a glacier in balance.
- Find the average ice flux per unit width for this cross-section.
- Find the depth- and width-averaged velocity of ice flowing through this cross-section.
- Knowing that there is drag from the sides and the bottom, use your averaged velocity to make a rough estimate of the actual speed of a marker on the surface at the center-line. Explain your assumptions

OK, after hearing the other group reports, now all groups answer Question 3.

(3) Synthesis

Both glaciers are 100 m thick and temperate. What factors might account for the differences in the estimates of the speeds of the markers at the surface on the center lines?