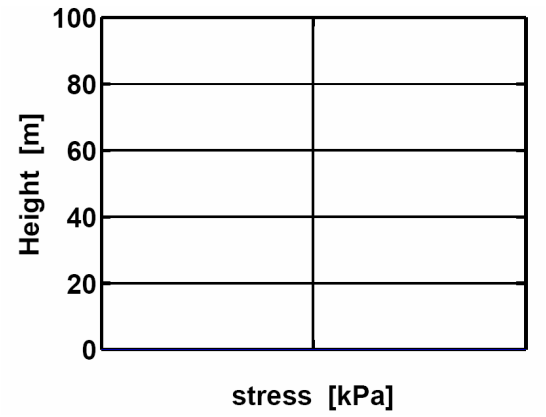
ESS 431 Principles of Glaciology
2009 October 23
Group Challenge – Ice Flow

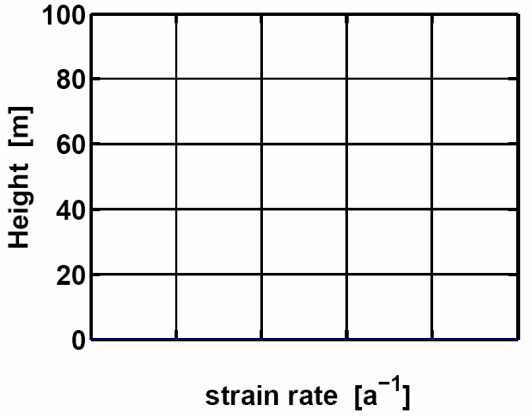
Find 1 or 2 partners, and work together to answer 1 of the following 2 questions. Before you start, designate a discussion leader, whose job is to keep the group on track, a recorder, whose job is to write down your group work, and a reporter, whose job will be to report your results to the class.

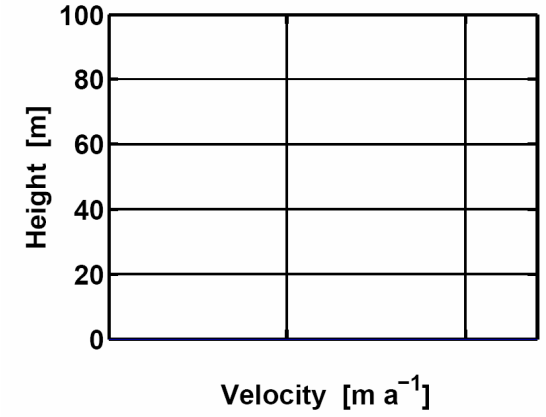
(1) Dynamic ice-flow estimation

A temperate glacier is 100 meters thick, with a slope of 6.3° (0.11 radian). The glacier is not sliding. Your coordinate system has *x* along the flow direction, and z is vertical. 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). (Don't over-do the significant figures ☺)
- Plot your results.
- Using Glen's flow law for ice at 0°C, estimate the shear strain rate $\partial u/\partial z$ at the same 6 depths.
- Plot your results.
- Without using the velocity formulas in the class handouts, estimate how fast the ice might be moving at each depth. (You can use the template on the next page.)
- 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 cross-section of particular interest to some UW glaciologists, 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.
- 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?