Glaciology 4888 final exam Humphrey, May 2021

1.5 hours, open book. This exam is open notes and open internet, but please no collaboration or consultation. The questions require minimal calculations (this is a hint). Numbers in '[x]' show approximate point values. Total points: ~35. For multipart questions, please label your answers (a,b,c etc.). Since there are 10 questions you can not afford to spend more than 10 minutes on a given question. The last question is a bonus, you can get full marks without it. Use separate sheet(s) to answer, and please try to be neat. You will need to email a readable scan/photo of your final exam to 'neil@uwyo.edu' within 15 minutes of the test end, unless you have made other arrangements. (Note if you run into problems, you can take a quick confirmation photo of your work with your phone or whatever and then send me something of a higher quality later.)

1. [8] (quick answer) *Questions:*
   a) Does ice get softer or harder (to deform) with increasing temperature?
   b) Does ice get softer or harder (to deform) with increasing pressure?
   c) In a period of warming climate (such as now), some glaciers, including central Antarctica are growing. Why or How?
   d) the horizontal surface glacier velocity caused by ice deformation is some power law of the ice depth. What is that numerical power?
   e) Is the water pressure in a linked cavity basal system typically higher or lower than in a basal water conduit system?
   f) How are glacier depth and surface slope related, for most glaciers?
   g) Do you find more **striations** where the ice was extending or compressing near the bed?
   h) what are 2 of the main factors that determine the depth of permafrost.
2. [5] You are a geologist looking at a large gravel pit on the Canadian border. A freshly cut, 50 ft high, face has a beautifully exposed sequence of beds recording the advance and retreat of a lobe of the continental ice sheet. *Question:* Describe what you see in the walls of the pit in a sketch, with labels showing what is exposed. (a **labeled** sketch is needed)
3. [2] We talked about the energy that is generated by the internal deformation of the ice, basically the stress times the strain rate. What happens to the internal strain energy in (a) polar, or in (b) temperate glaciers?
4. [4] The Malaspina Glacier in coastal Alaska is the largest ice mass outside of Antarctica and Greenland. Its ablation region is very low angle at about 0.5 degree (sin(.5) is about 0.009) and fans out across a low plain to the ocean. Near the terminal moraines the ice is still well grounded, with the ablating ice surface about 500m above sea level. *Question:* How far below sealevel is the basal ice of the Malaspina Glacier near its terminus?
5. [3] Bench Gl. In Alaska gets vast amounts of snow in winter, sometimes over 50ft! The net accumulation is close to 5m. Likewise the ablation rate in the lower ablation zone is very large, about 4m per year. The glacier is fairly small, only 10km long, 200m deep and a uniform 1km wide. *Questions:* a) how far up from the snout would you expect the approx. ELA. b) If climate changes and winters bring more snow [lets say an extra

½ m of snow, but summer melt stays the same]. How far would you expect the glacier to lengthen? c) give a time scale for the response.

6. [4] *Questions:*
   a) A ice sheet on relatively flat topography has a characteristic depth profile as you go inland from the margin, what is the shape of that profile?
   b) An ice sheet that ends in an ice-shelf typically has an upward concave surface profile near and below the grounding line, why?
   c) Why is there a bedrock sill or accumulated debris at the mouth of most fiords?
   d) Southern Greenland ice sheet is further south than the Latitude of Anchorage, Alaska or St. Petersberg, Russia, which have no ice. However, southern Greenland is covered in a thick ice sheet. What is the main factor or process that allows the ice in Greenland to exist under current conditions?
7. [3] Draw a sketch detail of our class regelation experiment. Draw a cross-section of the wire (a round circle) being forced through ice. Label with arrows the direction of **wire motion**, the path and direction of **water flow**, and the direction of heat flow. Label with "M" the peak location of melting, with "F" the location of freezing and label the coldest location with a "C".
8. [2] You are working near the snout of a glacier, and you can measure movement in the ice. You observe the ice sliding velocity (0.05m per day) and you also see the ice 10m above the bed is moving 0.055m per day.
   a) What is the approximate yearly shear strain rate in the basal ice?
9. [3] *Questions:* Sketch a **side** view of a short section of a valley glacier.
   a) sketch the velocity profile, due to internal ice deformation. Label the ice surface and bed.
   b) Put another profile on your sketch showing the shape of the shear strain behavior with depth, in other words plot ε_{xz} with depth.
   c) Add the driving stress profile (τ_{xy}). (you have done this before, so make this one neat and tidy!)
10. [2] A question on the power law behavior of ice.
    a) If ice is flowing over a bedrock bump, and the only stress is the basal shear stress (10^5 Pascal) and the ice is deforming under that stress. How much faster will the ice deform (strain) in the flow direction if the basal stress is doubled.
    b) (hard) If the ice is also squeezed sideways to flow (by adjacent bumps) with a stress of 10^3 Pascal, so there are two stresses in the problem (basal and squeezing). Approximately how much faster will the ice squeeze (strain) in the cross flow direction if the squeezing stress is doubled?
11. [4][this question is designed to keep you busy if you finish early, it requires **very** clear thinking] Central West Antarctica is currently sitting on land that is up to 1000m below sealevel, while the ice surface elevation is up to 3000m above sealevel. The ice has been there for over 100,000yr. If it was to break up and float away, isostatic rebound would eventually lift the sub-sea region to approximately sea-level. The volume of ice in all of West

Antarctica is about 2.2million km^3, the **average** ice height above sealevel is about 1500m, while the depth below sealevel **averages** 500m.
Questions: a) If 1 km^3 of ice melt raises sealevel by about 1/400mm, how much will sealevel respond (extra extra points, warning difficult) including subsequent isostacy, would a breakup of west Antarctica create?