Glaciology 4888/5888 final exam Humphrey, May 2015

2 hours, open book, 2 pages (12 questions) 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: 45. I have labeled the part of the question you are to directly answer with '*Question:……...?'.* For multipart questions, please label your answers (a,b,c etc.). Since there are 12 questions you can not afford to spend more than 10 minutes on a given question. Use separate sheet(s) to answer, and please try to be neat.

1. [5] (6 quick questions) *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) Why does water expand on freezing? d) horizontal surface glacier velocity that depends on ice deformation is related to some mathematical power of the ice depth. What is that power? e) Is the water pressure in a linked cavity basal system typically higher or lower than in a basal water conduit system? f) What is the approximate relationship between glacier depth and surface slope, for most glaciers?
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. (a labelled sketch is needed)
3. [4] You are doing a basal ice experiment, and place 3 similar-sized hemispherical bumps on the glacier bed. You then let the glacier flow over the bumps. Two of the bumps are made of rock and one is made of copper. The copper bump is 1cm high, while the rock bumps are 1cm and ½cm high. *Question:* a) Place the bumps in order of the expected normal stress on the upstream face and very briefly explain your ordering? (hint: Copper has many times the thermal conductivity of rock). *Question:* b) If the sizes (above) were in meters instead of centimeters, now what would be the order?
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 ablation ice surface is about 500m above sea level. *Question:* How far below sealevel is the basal ice of the Malaspina Glacier near its terminus?
5. [3] The Bench Gl. In Alaska gets vast amounts of snow in winter, often over 50ft! The net accumulation is also large, close to 10m. Likewise the ablation rate in the lower ablation zone is very large, also about 10m per year. The glacier is fairly small, only 10km long, 200m deep and a uniform 1km wide. *Question:* Estimate a time scale for the Bench glacier to respond (by about 87%) to a change in climate.
6. [4] *Questions:* a) A grounded ice sheet 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 upwards concave surface profile near and below the grounding line, why? c) An ice shelf is

not in force balance with the ocean; try to explain the force balance that causes the ice to stretch and crack in the ice shelf.

7. [3] *Questions:* a) Give at least 3 mechanisms to get rock and debris into basal ice? b) Do you find more striations where the ice was extending or compressing near the bed? c) There isn't much snow left on the hills east of Laramie. What is the shape of the grains in the remaining snow, and give the basic reason why the grains have that shape. d) In a period of warming climate (such as now), some glaciers, including central Antarctica are growing. Why or How?
8. [4] Central West Antarctica is currently sitting on land that is 1000m below sealevel, while the surface elevation is about 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. The volume of ice in all of West Antarctica is about 2.2million km^3, the average height above sealevel is about 1500m, while the depth below sealevel averages 500m.

   Question: a) What would be the final elevation of the land under central West Antarctica relative to sealevel?

   Question: b) If 1 km^3 of ice melt raises sealevel by about 1/400mm, how much will sealevel rise if the ice sheet catastrophically breaks up (ignore isostacy)?

   Question: (extra points, warning difficult) c) Would the subsequent isostatic rise of west Antarctica cause a change in sea level (and which way)?
9. [3] Why is the ablation region on a typical steady state glacier smaller than the accumulation region?
10. [4] 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. *Question:* a) What factors or instabilities are related to the present Greenland icesheet, b) what instabilities may play a role in its future demise, if global warming continues?
11. [3] 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) *Question:* What is the approximate shear strain rate in the basal ice? b) *Question*: What is the approx.. magnitude of the ablation rate (per year) in the region of this glacier snout, assuming the glacier is close to steady state.
12. [3] *Questions:* Sketch a side view of a short section of a valley glacier. a) sketch the deformation velocity profile. 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. (For an extra bonus point you should draw or state the difference in the curvature between the two profiles). c) Add the driving stress profile (τ_{xy}).