

A. Glacier Geography

1. (3 pts) What is the relevance of glaciers to human living conditions? (first day of class)
2. (2 pts) Define a glacier.
3. (2 pts) What is the fundamental condition for glacier formation?
4. (2 pts) Name the continent(s) on which glaciers do not exist.
5. (3 pts) Name the two major ice sheets and, roughly speaking, what is the ratio in areas?
6. (2 pts) Define a tidewater glacier and explain how it differs from an ice shelf.
7. (2 pts) How does an ice cap differ from an ice sheet?
8. (3 pts) For a glacier located in the Wind River Range of Wyoming, please provide three descriptive terms that help to classify it.
9. (3 pts) How does a surging glacier differ from a normal glacier?
10. (3 pts) What is an ice stream and where are they located?
11. (3 pts) What are the thermal descriptions of a glacier and why are they particularly important?
12. (1pt) From an aircraft, how can you tell the difference between a snowfield and a snow-covered glacier?
13. (3pts) Glaciers exist in the Sierra Nevada and reach down to about 10,000 feet. Glaciers in the North Cascades, Washington reach down to about 5,000 feet. Why the difference?

B. Ice Physics and Glacier Structure

1. (5 pts) Water phases and transitions.
 - a. Name the three different phases of water (do not include clathrate).

- b. Name the three kinds of phase transitions and identify the phases involved. Please order them from least energy required to greatest energy required.

LEAST _____

GREATEST _____

- c. Describe why different energies are required for the different phase transitions.

2. (2 pts) Draw the plan view and side view of the molecular structure of 1h ice. Show the oxygen atoms as solid dots and the hydrogen atoms as open circles. Include in each diagram the direction of the c- and a – axes.
 3. (2 pts) Draw a snowflake and indicate the c-axis and a-axes.
 4. (3 pts) Why is the c-axes important? Please describe.
 5. (4 pts) What is the relationship between pressure and melting temperature of ice? Why is this important, glaciologically speaking?
 6. (2 pts) What is the hardness of ice? You don't need to quantify it, just roughly, how hard is it? Can it scratch bedrock?
 7. (4 pts) Describe the processes by which snow transforms into ice include both the dry processes and the wet processes. Do dry and wet processes occur on all glaciers? Clarify.
 8. (2 pts) Describe compaction.
 9. (3 pts) Describe sintering.
 10. (3 pts) Once ice forms, the glacier continues to metamorphose. Describe the solid state transformations that recrystallize and reorient glacier ice.
 11. (3 pts) How do ice crystals (not snow crystals) in the glacier, initially randomly oriented evolve in a glacier such that near the bottom of the glacier the c-axes are all oriented vertically? Explain both the process than drives the change and the microphysical processes that cause the change.
- Similar to 11:
12. (3pts) Both the size and orientation of ice crystals (not snow crystals) change with depth in an ice sheet or glacier. In what way to they change and why? How does it affect the flow of the ice sheet?

13. (4pts) What is the equation relating the stress and strain-rate for ice? This is known as “Glen’s flow law”. Identify all terms and extra points for getting the units right.

14. (2pts) Describe the effects of temperature and impurities on the viscosity of ice.

15. (2pts) Snow metamorphoses into ice. What is the metamorphic transitional stage called between snow and ice, and how is it defined?

16. (4 pts) Describe the processes responsible for causing the deterioration of the shape of faceted ice crystals into more rounded shapes. Assume temperatures remain below freezing and the crystal is unaffected by neighboring crystals.

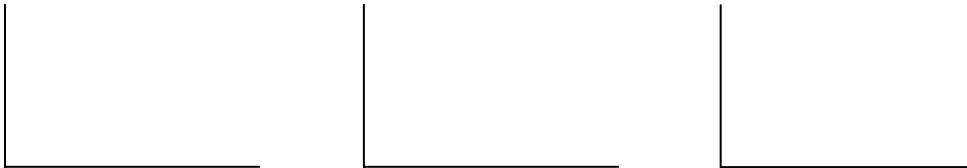
17. (5pts) Explain the transformation process from snow to ice for, (a) temperate glaciers; (b) polar glaciers. Also explain which is faster, and in which setting the transition from snow to ice occurs at shallower depths.

C. Mass balance and movement

1. (3 pts) Glaciers and ice sheets exist due to a balance between mass accumulation and ablation. Identify the ways ice mass accumulates and ablates.

2. (3 pts) A glacier (or an ice sheet) can be divided into two parts, the accumulation zone and the ablation zone. Describe each and how they differ. What is the name of the dividing line between them.

3. (4 pts) For a glacier on Mount Hood graph the mass balance versus time for one year. Focus your attention on three points on the glacier, one in the accumulation zone, one in the ablation zone and one on the line in between. Draw a separate graph for each site, and use the seasons (F, W, S, S) for time on the abscissa. Label all parts of all graphs.

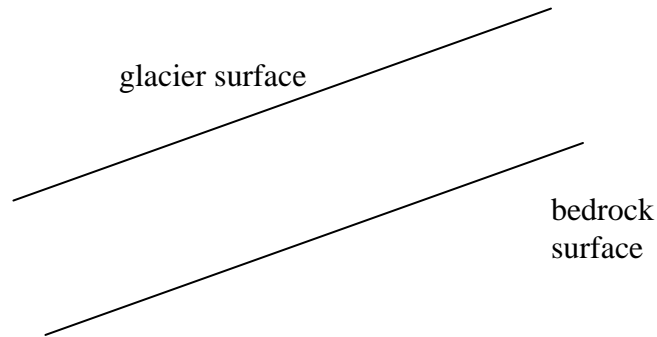


4. (4 pts) How would you remotely measure the mass balance of part of Antarctica that resides on bedrock? Use the continuity equation and describe how you would evaluate each term. Please discuss uncertainties.

5. (3 pts) What does AAR stand for? Please define it, and briefly explain its usefulness.

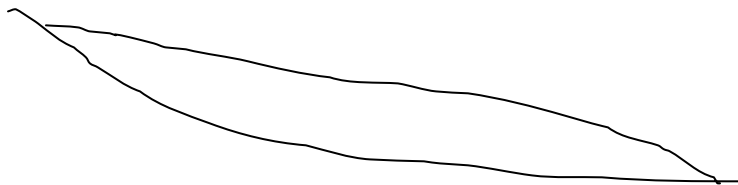
6. (3 pts) Describe the relation between the ELA and glacier mass balance. Drawing a graph of ELA on the y-axis and balance on the x-axis will help your explanation.

7. (5 pts) Draw the force diagram for a glacier with an inclined surface at a constant slope and constant thickness lying on a parallel bedrock surface. Label all vectors. Be careful with this drawing such that the geometry of the vectors makes sense.



8. (3 pts) What is the equation for the shear stress at the bottom of a glacier? Define each term and include units. Show that the units work out.

9. (3pts) On the longitudinal (down glacier) cross-section of a glacier show the flow lines in the ice and direction of movement. Include the position of the equilibrium line for reference.



10. (4 pts) How do glaciers flow down slope? That is, what two mechanisms exist? Do all glaciers flow this way? What is the relevance to landscape modification?

Flow processes: a. _____; b. _____

11. (6pts) Do all glaciers utilize both flow mechanisms, why? What is the relevance to landscape modification by glaciers? Explain how landscape modification might differ.

12. (6pts) Describe in pictures and words the regelation process, which controls the movement at the base of the glacier. Include directions of ice flow, water flow, and heat

flow. Also explain, in words, the order of the thermodynamic processes. That is, what happens first, then what happens second, and so on?

13. (4 pts) How does water pressure affect glacier movement? Please describe.

14. (5 pts) A glacier changes speed from winter to summer and from early part of the day to latter part of the day. Please describe this change in motion and explain why it happens.

15. (2 pts) The critical shear stress for ice is 1 bar (10^5 Pascals). What does this mean, that is, what is meant by the critical shear stress for ice?

16. (2 pts) Define ablation.

D. Energy Balance

1. (8 pts) Write the basic equation for the energy balance at an ice surface. Don't forget that it sums to zero. Define all terms, of course.

2. (4pts) Write the functional relationship for latent heat flux. (Functional relationship, what variables (not constants) in the numerator/demoninator that govern the physical relation between them and the resulting latent heat)

3. (4pts) Write the functional relationship for sensible heat flux. (Functional relationship, what variables (not constants) in the numerator/demoninator that govern the physical relation between them and the resulting latent heat)

4. (7pts) Define, sensible heat, latent heat, shortwave radiation, long wave radiation, albedo, sublimation, and evaporation.

5. (4pts) All other weather variable the same, what happens to the energy balance when the surface is snow covered versus ice covered?

6. (4pts) All other variables the same, what happens to the energy balance when the wind speed increases?

7. (6pts) Describe how the energy balance on a glacier surface will change with elevation on a glacier. Choose 3 locations, mid ablation zone, equilibrium line, and mid accumulation zone. Please include an altitude so I know how high you are going.

8. (6pts) At what point on the glacier is the energy balance, when solved for melting, equal to snow fall. What does this imply?

D. Glacier Hydrology

1. (4 pts) What are the effects of glacier melt on runoff in alpine watersheds compared to basins with no glaciers? Your answer must illustrate your knowledge of glacier effects as opposed to just snow effects.
2. (3 pts) What is the pattern of diurnal variations in runoff from a glacier and how does it change from early in the season (late May) to late in the season (late August)?
3. (9 pts) A glacier cross-section can be divided into 3 main zones, supraglacial, englacial, and subglacial. Identify the hydraulic features (components) that govern water flow in each zone.
4. (5pts) For the subglacial system describe the hydraulic mechanics of the two main systems that route most of the water flow. That is, how can they stay open under hundred's of meters of ice? Clue: Till is not one of the systems.
5. (4pts) Describe several methods to investigate how water flows through a glacier.
6. (4 pts) What are the processes keeping a conduit open? That is, why doesn't the ice squeeze closed? What is the pressure difference between large diameter passages and small ones? Explain the process.
7. (4 pts) What are the processes keeping a cavity open? That is, why doesn't the ice squeeze closed?
8. (4 pts) A subglacial conduit and a link-cavity system operate very differently. Explain.
9. (3pts) What causes an outburst flood?
10. (5pts) Describe the relevance of subglacial hydrology to glacier motion including surging.
11. (3 pts) How do subglacial cavities affect glacier sliding? Explain the process.
12. (2pts) How does subglacial till affect glacier movement? Explain the process.
13. (8pts) (a) Draw a cross-section of a temperate glacier and identify the major hydrologic processes by which water gets from the surface to the bed. Be sure to include both the accumulation zone and the ablation zone. Identify features on your diagram. (b) Which, if any, of these processes occur on a polar glacier where summer temperatures barely reach 0°C and only for a few weeks.

14. (4pts) Two main subglacial hydraulic systems were discussed in class. These two systems convey the majority of the subglacial water. Identify each and explain how each works.