EARTH AND SPACE SCIENCES **Autumn 2018**
431 *PRINCIPLES OF GLACIOLOGY* 4 Credits, SLN 14855
505 *THE CRYOSPHERE* 4 Credits, SLN 14871

Midterm Exam Practice Questions
Midterm: Friday November 9, 2018, 130-250 pm, JHN 127

Instructions: This exam will consist of three components: (1) vocabulary/terminology/short definitions (questions could ask for prose explanations or ask you to explain the terms in an equation), (2) conceptual questions requiring short answers but no calculations, and (3) questions that will require some simple calculations. The sample topics and questions given in this study guide are designed to be representative of the types of questions we will ask on the exam. This is not an exhaustive list of every question we may ask (though some of the questions on this guide could also be on the actual test), but these questions are a reasonable facsimile of the type and difficulty of the questions that will be on the test. Some of the questions here may require you to refer to notes for the values of constants. Any constants you require on the test will be provided. We will also provide equations that are not listed in bold in the vocabulary section below. You will not be permitted any materials besides a calculator on the exam (no equation sheet).

I. Vocabulary, ideas, and equations you should be able to talk about intelligently:

1) Components of the cryosphere
2) Remote sensing the cryosphere
3) Densities of ice and water
4) H2O molecular bond angle
5) Phase diagram of ice
6) Energy / temperature / phase transitions
7) **Fourier's Law***
8) Thermodynamic properties / units
9) Intuition behind the latent heats (magnitudes)
10) Cloud / ice condensation nuclei
11) Vapor pressure (curvature? temperature?)
12) Crystal growth (role of humidity)
13) Types of snowpack metamorphism
14) **Surface energy balance***
15) **Constitutive relation / Glen's Flow Law***
16) **Strain rates***
17) Weertman sliding (regelation / EC)
18) Distributed vs. channelized hydrology
19) Ablation mechanisms in ice
20) Marine ice sheet instability
21) The role of ice shelves in ice flow
22) Surging glaciers
23) **Sensible heat***
24) **Latent heat***
25) **Glacier response timescales***
26) Glacier disequilibrium
27) **Diffusion (heat) equation***
28) **Peclet number***
29) **Finite difference solutions***
30) Glacier mass balance
30) **Gravitational driving stress***
32) Basal shear stress
33) **Clausius-Clapeyron relation***
34) **Dynamic description of glacier flow***
35) **Kinematic description of glacier flow***
36) Glacier mass balance zones

***you should know the form of these equations/mathematical relationships**

II. Practice Conceptual Questions

1) Components of the cryosphere. The cryosphere is composed of ice stored in a variety of reservoirs and forms. Some components may be more responsive to short-lived excursions in seasonal weather patterns than others.
    a. Suppose that the event is 5 successive unusually cold and wet winters.
        - Identify a component of the cryosphere that you would expect to change significantly in response to this excursion event.
        - Describe how this cryospheric component would change, and why. Describe how this change in the cryosphere might in turn affect the long-term weather, or the climate.
        - Identify a component of the cryosphere that would **not** change significantly in response to the above event. Why not?

    b. Suppose that the event is 5 successive unusually warm, sunny spring seasons.
        - Identify a component of the cryosphere that you would expect to change significantly in response to this excursion event.
        - Describe how this cryospheric component would change, and why. Describe how this change in the cryosphere might in turn affect the long-term weather, or the climate.
        - Identify a component of the cryosphere that would **not** change significantly in response to the above event. Why not?

2) Glacier flow. The shear stress at the base of a glacier generally falls in a fairly narrow range near 1 bar (10^5 Pa), with variations of typically less than a factor of 2. Glacier speeds, on the other hand, span a relatively wide range, from 10^0 to 10^3 meters per year.
    a. What are the physical causes for these two behaviors?
    b. Why are their percentage ranges of variation so dramatically different?

3) Ice in clouds
    a. Describe the primary differences in characteristics and relative abundances of cloud condensation nuclei (CCN) and ice-forming nuclei (IN).
    b. In a cloud at a temperature of -15°C, explain how the difference in abundance of CCN and IN allows rapid growth of ice crystals to sizes large enough to precipitate.

4) Deformation of glacier ice.
    a. Describe how the structure of ice crystals (atomic arrangement and bonding) allows ice to flow when a stress is applied.
    b. Why do imperfect ice crystals deform more easily than perfect crystals?
    c. Why is colder ice harder to deform than warmer ice?

III. Practice Calculations

1) A 100m thick glacier has a surface temperature of -20°C. The thermal conductivity of glacial ice is 2.3 W/(m°C) and the heat flux into the base of the ice is 0.06 W/m^2. What is the temperature at the base of the glacier?

2) How much energy does it take to raise 10g of ice 20°C? How much energy does it take to raise 10g of water 20°C? How much energy does it take to melt 10g of ice? How much energy is released when 10g of water vapor condenses to dew?

3) What is the shear stress at the base of a glacier with uniform thickness of 300m, sitting on a bed sloping at 5°? What is the strain rate at the base of that glacier, assuming a rate factor of $2*10^{-16}$ (Pa^{-3} A^{-1})? What are the units of strain rate?

4) In the accumulation zone of a glacier, the average accumulation rate is 0.1m/a over a rectangular area 200m x 100m. What is the average speed through the equilibrium line, given a glacier width of 100m and an average ice thickness of 30m? Is this a dynamic framework for thinking about glacier flow or a kinematic framework?