Final Examination

Geography 4321/5321, Snow Hydrology

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This is an **open book** final exam. You are to work in assigned teams. However, each student must turn in their own separate final exam. Please begin each answer on a separate page; please include each question with the answer. You have to until 4:30 pm to turn in the final. Obviously, you are welcome to finish earlier. Please place it in my mailbox in Geography.

There are 300 possible points on this test.

1. Explain why individual snow crystals are hexagonal but the repeating crystalline element of ice is a tetrahedron. Include in your answer these keywords: dipolar, crytalline lattice, hydrogen bonding, a-axis, c-axis, molecular structure of water, covalent bonding, electron, positive charge. Use at least 3 figures in your answer. 20 points.

2. Describe the release mechanisms of dry slab avalanches. Include in your answer shear stress, slope angle, appropriate forces, and nomenclature of slabs. Use at least two figures in your answer. 20 points.

3. What is surface hoar? What is the importance of surface hoar when evaluating avalanche danger? What are the meteorological and energy balance conditions that result in the formation of surface hoar? Use a diagram in your answer. Include in your answer these terms: longwave radiation, wind speed, air temperature, day time, night time, saturation vapor pressure. 20 points.

4. Explain why kinetic-growth snow crystals (TG or depth hoar) may form above or below ice lenses within a snowpack, regardless of the temperature gradient. Use a diagram in your answer. 20 points.

5. Compare the following two situations in terms of the *relative* importance of the sources of energy for snowmelt (radiation, sensible and latent heat exchanges): (a) a dense forest at an elevation of 2500 m, and (b) an open alpine area above tree-line. Include in your discussion the *relative* spatial distribution of these energy fluxes. 20 points.

6. Why is a temperature-gradient of 10°C m^{-1} needed to form kinetic growth crystals at snow temperatures near 0°C and a temperature gradient of 35°C m^{-1} at snow temperatures close near –20°C? Use a diagram in your answer. 20 points.

7. What information about snow's physical properties can be obtained from remote sensing of snow in visible and near-infrared wavelengths. What principles about the optical properties of snow are used to make these determinations? Describe briefly the advantages and disadvantages of AVHRR, LANDSAT, and AVIRIS for measuring snow properties. Use at least two figures in your answer. 40 points.

8. For the following snowpack: graph density, temperature, and stratigraphy. Calculate SWE and the average density. Use the snowpit information to interpret the climate history that lead to the formation of this seasonal snowpack. 40 points. 8..TS

height m	density kg/m^3	temperature °C	comments
1.00	350	-5	ET
0.90	350	-4	ET
0.80	350	-4	ET
0.70	350	-4	ET
0.60	350	-4	ET
0.50	400	-3	ET
0.40	750	-3	Ice lens
0.30	400	-3	ET
0.20	300	-2	TG
0.10	300	-2	TG
0.00	300	-1	TG

8..sp

9. You've been given a $2,000,000 grant to conduct a research project on the sensitivity of stream water in North Boulder creek to acid rain/snow. Design the research project. 50 points.

10. You have meteorological measurements located 2 meters and 50 cm above the snow surface. It hasn't snowed lately and the direct beam albedo of incoming solar radiation is 0.65, while the diffuse albedo is a little much lower at 0.40. It's a cloudy day,

so incoming shortwave radiation is 520 W/m^2 and diffuse radiation is 390 W/m^2. It's windy, with a wind speed of 6 ms^{-1} at the upper height and 3 ms^{-1} at a height of 50 cm above the snow surface. Snow pack is isothermal at a temperature of 0°C. Air temperature at the higher insturment is is 2.5°C and at the lower instrument is 1 °C. Atmospheric temperature is 3°C. Cloud height is 30 meters. Atmospheric emissivity is 0.3. The specific humidity at the upper measurement height is 0.0055 and the specific humidity at the lower instrument height is 0.006. View factor is 0.6. The emissivity of the terrain is 0.2 and the terrain temperature is 1°C. Snow density is 510 kg m^{-3}. Ground heat flux is 25 W/m^2 and reaches the snow surface because the snowpack is isothermal and has a high density (e.g. high thermal conductivity). 50 points.

- Calculate the energy balance of the snowpack.
- How much snowmelt would you get over the time period of one hour?
- Recalculate the energy balance, assuming that you have a thin snowpack, 50% of net incoming solar radiation penetrates through the snowpack to the underlying ground, the ground has an albedo of 0, and that all of the energy reaching the ground becomes ground heat flux to the snow surface.