GEOG/METEO 5260
Snow and Avalanche Dynamics, Spring 2017
Midterm 2 (Take Home)

Name:

1.	__/20	6.	__/10
2.	__/15	7.	__/10
3.	__/12	8.	__/20
4.	__/20	9.	__/5
5.	__/10		

TOTAL ___/

This exam consists of 9 problems. It is due Wednesday, April 12th at 6 pm. You can either print it and bring it to the end of semester get together, or email to Steven. stevenclarkslc@gmail.com

1. Snow Metamorphism (20 pts):
Complete the table.

<table>
<tr><th>θ</th><th>Metamorphism Regime</th><th>Water Content</th><th>$\partial T/\partial z$</th><th>Bonding Characteristics</th><th>Resultant Crystals</th><th>Growth Rate</th></tr>
<tr><td rowspan="2">DRY</td><td></td><td rowspan="2"></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">WET</td><td></td><td></td><td rowspan="2"></td><td></td><td></td><td></td></tr>
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</table>

2. Shear/Tensile Table (15 pts)

Location: Far Away Time: 0900 Observer: Bobby McGee Date: 14 March, 1968

Elevation: 8900 ft Aspect: 360 Slope: 30° Sky: Clear Air Temp: -14 °C

Layer #	Depth	Hardness	Grain Type	Density (kg/m^3)	Shear Strength (Pa)	Temperature (°C)
1	320					
		Fist	New snow (dendrites)	120	340	-8
2	290					
		4F	Partially decomposed	150	850	-6
3	240					
		1F-	Rounds	240	2,200	-5
4	140					
		1F+	Facets	130	2,000	-5
5	120					
		P	Rounding Facets	200	3,800	-4
GROUND						-1

A. Following the AAA Guidelines (Snow, Weather, and Avalanches) draw the pit profile using the data from the table above. (10 pts)

B. Compute the shear stress acting on the bottom of each layer. (5 pts)

C. Which layer will fail first given some added stress to the snowpack? (2 pts)

D. If the slope angle were to change, at what slope angle will failure in shear occur for each layer? (5 pts)

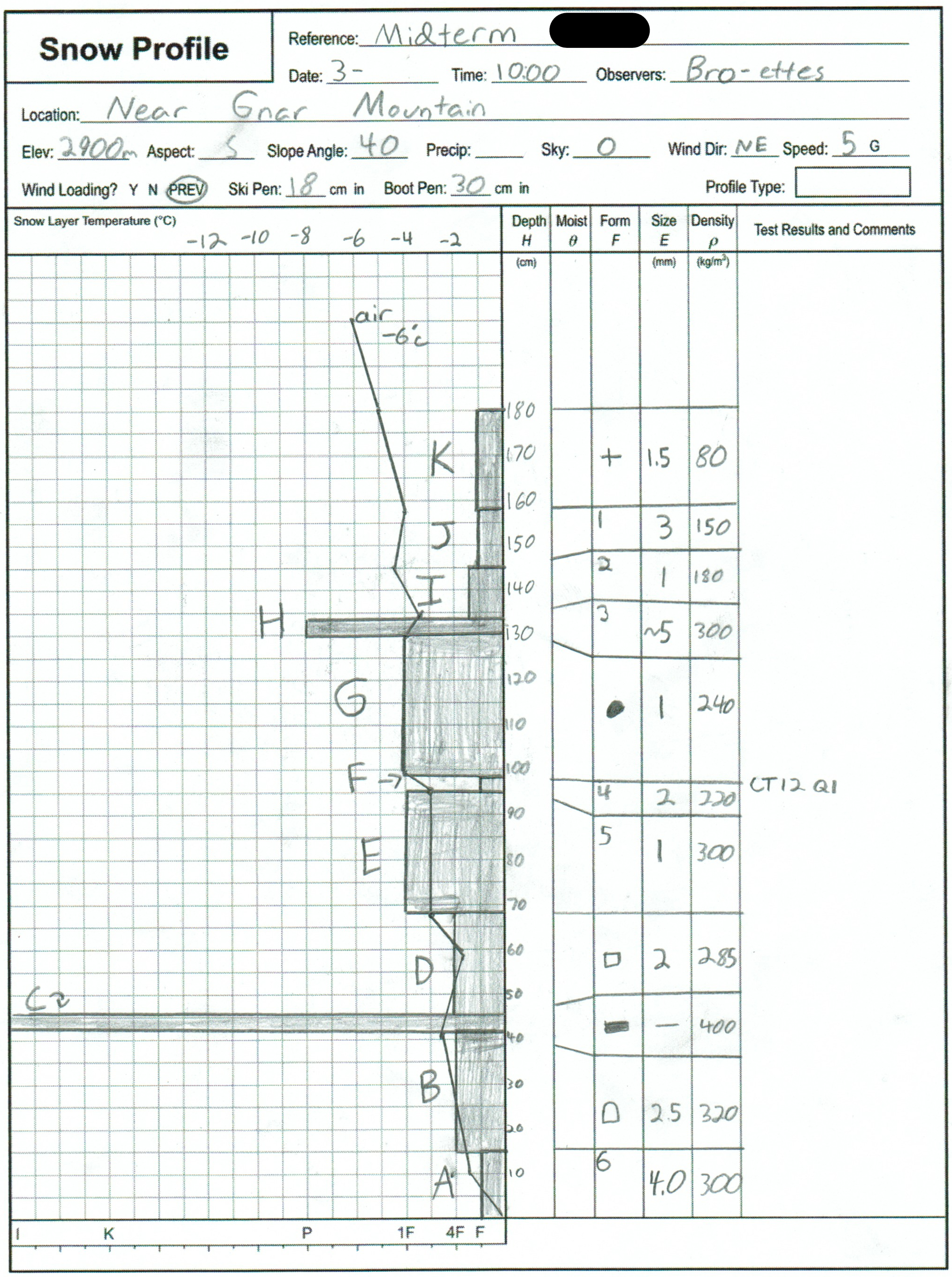
E. Compute the tensile stress above the weak layer (determined in question #3). Assume that L_S = 7 m. (3 pts)

F. Calculate the maximum slope angle before failure in tension in the weak layer. (3 pts)

G. How much extra weight on the snowpack would result in a failure in shear in the weak layers? (5 pts)

H. How would you evaluate the stability of this slope? Would you ski it? Why or why not? (5 pts)

Use this pit profile for problems 3 and 4.



Snow, Weather, and Avalanches

Snow Profile

Reference: Midterm [redacted]
Date: 3- Time: 10:00 Observers: Bro-ettes
Location: Near Gnar Mountain
Elev: 2900m Aspect: S Slope Angle: 40 Precip: ____ Sky: O Wind Dir: NE Speed: 5 G
Wind Loading? Y N (PREV) Ski Pen: 18 cm in Boot Pen: 30 cm in Profile Type: ____

Snow Layer Temperature (°C): -12 -10 -8 -6 -4 -2

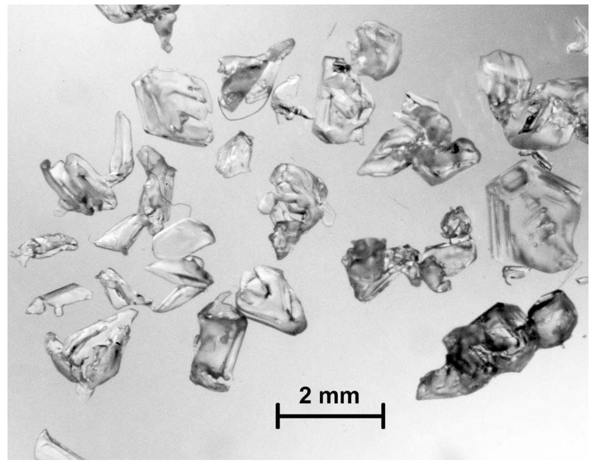
air -6°C

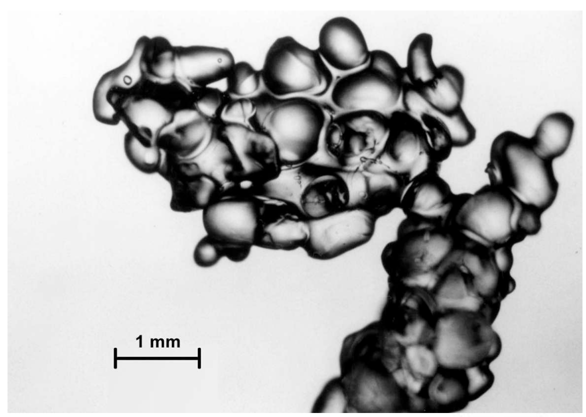
Layer	Depth H (cm)	Moist θ	Form F	Size E (mm)	Density ρ (kg/m³)	Test Results and Comments
K	180		+	1.5	80	
J	160		1	3	150	
I	150		2	1	180	
H	140		3	~5	300	
G	130		●	1	240	
F	100		4	2	220	CT12 Q1
E	90		5	1	300	
D	70		□	2	285	
C	50		▬	—	400	
B	40		∩	2.5	320	
A	10		6	4.0	300	

Hardness: I K P 1F 4F F

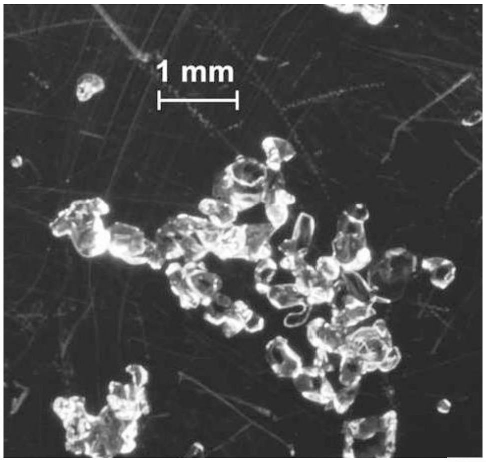
3. Pit Pluggin' (12 pts)

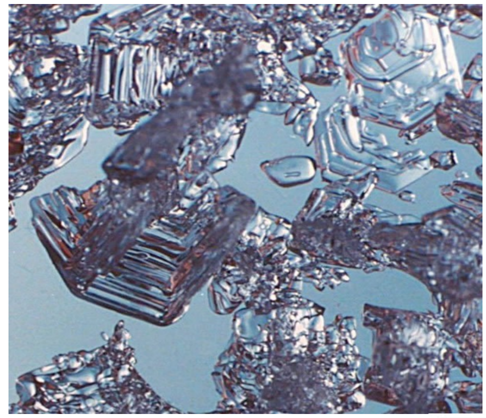
A. The following crystals were found in the pit found on the previous page. Identify and write out the names of the crystal types in the spaces below. Also, put the ICSI symbol for each crystal type in the box below each picture.





There's two more on the next page...





B. **Then, based on what you can infer from the profile, use this information to complete the Form column on the pit profile. (Hint: it will be easier to work on the following problem first and fill it in as you go).**

4. **Weather and the Snowpack (20 pts):**

Circle the most appropriate answer, using the pit profile on the preceding page.

The bros at Rho Sigma Psi are bummed. It's been a rough season up at Gnar Mountain. It started out early with big dump in early November, and temperatures stayed (*balmy / cold / variable*), but there was no more snow for at least a month. Meanwhile, the November snow was (*sinter / melt / facet)* -ing as the bros prepared for Initiation Week: the large temperature gradient in the relatively (*deep / wide / shallow*) snowpack initiated a (*pendular / equilibrium / kinetic*) metamorphism regime. While they were home for Grandma's Thanksgiving dinner, they missed a storm which formed layer B. Layer B was exposed to (*a lesser temperature gradient / more riming / more solar radiation*) than layer A. During finals week another big trough came in, but they glumly stared at the Gnar Mountain webcams as it (*graupeled / snowed / rained*), forming layer C.

Then, their luck seemed to turn around. Those of the bros who stuck around at the frat house over winter break skied sick pow when several cold storms from the northwest came in. At night, they liked to watch the infrared satellite loop, which shows the (*longwave / incident / shortwave*) radiation received by a satellite orbiting the earth. By the time spring semester started, however, the storms dried up. Layer F was formed during the (*cold and clear / hot and heavy / cold and cloudy*) nights during that period, which the bros knew was coming when they saw a huge (*ridge / trough / vortex*) headed their way on the satellite loop.

In late January, a storm came in that started out calm and cold, preserving layer F and forming layer G. A period of (*mild / very cold / warm*) daytime temperatures followed, forming layer H. The very high liquid water content between the snow grains at the surface created a (*pendular / funicular / kinetic*) metamorphism regime – the grains that form this layer are called (*sinters / polygrains / rounds*). It soon snowed a bit more, and another cold and clear period followed. The bros, who had been in Cancun for President's Day weekend and missed the storm, decided to ski the south face of Gnar Mountain when they got back. To their dismay, instead of blower pow, they found that layer I had become (*a melt-‐freeze crust / surface hoar / facets*), and had been formed by (*diurnal recrystallization / radiation recrystallization / the pendular regime*).

A strong frontal passage came through Gnar Mountain the next week, generating strong convection. Because the temperatures were between -‐6 and 0 C, there was a lot of (*freezing nuclei / supercooled water / columns*), which froze on contact with the new snow particles, forming the (*graupel / dendrites / polygrains*) in layer J. As the trough axis moved past the region colder air moved in, orographic precipitation kicked in and the convection stopped. This created a layer of 8% (*wet snow / powder / concrete*) on top of layer J. Assuming the orographic cloud formed at an elevation of 2000 m and temperature of -‐ 10C, and that all moisture had precipitated out at the summit (elevation 4000 m), the bros figured out that the temperature was (*-‐7.5C, +5C, -5C*) on campus (elevation 1500 m), located in the lee of Gnar Mountain. The skiing conditions were (*awful / epic / okay*) for the rest of the day, but 20 m/s winds kicked up that night, which was an issue because all the new snow began (*transporting / stiffening / sublimating*). Once again, when the bros arrived at the base of Gnar Mountain the next morning, they arrived too late, finding nothing but (*sastrugi, firnspiegel, runnels*) on their favorite runs.

5. Timeline (10 pts)

The weather timeline is a separate attachment in the email; you will need it to answer this question.

A. What day had the highest SWE for the 2016-2017 season? (2 pts)

B. Out of these three dates (A. February 12th B. January 13th, C. March 7th), what day had the best conditions for surface hoar formation? (2 pts)

C. You are going to make a weather timeline for the season at a new ski resort and can place two weather stations anywhere on the mountain. Describe the physical locations where you will place them. What weather information will you take from each site? (4 pts)

D. You dug a pit in the *new* snow that fell from January 8th to January 12th. Looking solely at the new snow, temperature, and snow water equivalent data, draw a hardness profile of your findings (2 pts)

6. **Snow Energy Balance (10 pts)**

   a. On Sunday March 5th there was sustained (pre-frontal) high winds from the south. That evening, and into the next day, ~50cm of new snow fell in the mountains as the front passed. On Tuesday, McKenzie went up Little Cottonwood Canyon to dig a pit- what was she looking for beneath the new snow layer?____________________________

   b. Look at the timeline, what are snow energy balance implications for what McKenzie found in the snowpit for the remainder of March? What happened to the Wasatch snowpack over this time period?

7. Mountain Meteorology (10 pts)

During the time period between 01/04/2017 – 01/05/2017, a winter storm impacted northern Utah, Using Mesowest, describe in detail the differences between the Sundance Mid Mountain (SNM) weather station and the Alta-Collins station (CLN). What influenced the disparity in precipitation between the two sites (hints: flow direction, topography, elevation)?

Helpful Mesowest ID's:
Sundance Mid Mountain – (SNM)
Arrowhead Summit – (SND)
Alta-Collins – (CLN)
Alta-Mount Baldy – (AMB)

8. **Wet Snow Metamorphism Story Problem (20 pts)**

Ralph loves spring skiing. He loves it because the snow consists of three things: ______________, __________________, and ________________. He also likes how the metamorphism rate in the snowpack is ______________ because _______________ is a ________________ conductor of heat than air. However, he doesn't like how the higher water content makes the snowpack __________________ stable. His favorite part of spring skiing is ____________ snow, which is formed by _____________ – _________________ ___________________.

On a warm spring day, Ralph sets off to enjoy some corn skiing. As he leaves the trailhead he takes a look at the snow. He picks it up and presses it between his hands, squeezing some water out. "What the #&@^ is this bull $#!%" he says to himself. But of course he knows that it's just snow in the _____________ regime with a water content from ______ to ______ %. "Maybe I should have gotten an earlier start before the ____________ wave, ___________ wave, and ____________ heat melted it to $#!%."

As Ralph starts to skin up, he notices __________ forming on steep slopes indicating that the risk of ___________ ___________ avalanches is on the rise. Just below a cliff off to the side that he passes by, he notices a ____________ crack that has started to open up from the __________ snowpack starting to slide down the hill.

After a couple hours of skinning up, he finally makes it to where he wants to ski. While there, he digs a snow pit on the north-facing aspect. He picks this aspect because it receives the least __________ _____________ and maybe he can salvage his day. He presses on the snow but nothing comes out. He looks at it under his loupe and sees ___________ water between the snow grains. "Aha, __________ regime snow!" He's excited because this snow is ____________ stable and ___________ to ski on, and has a lower water content than ___________-regime snow.

He begins his descent down the mountain and is really shredding the gnar. But as he gets lower, he begins to enter ________ water content snow. He makes some small _____________ ______________ avalanches as he goes down some steeper sections but doesn't think much of them. As he comes over the last roll-over, the water content has gotten so high that only the __________ ___________ of the water is holding the snow together. The melt has removed nearly all the ______________ between the grains, reducing the ______________ to the point of _____________.

Suddenly, a ______________ _________________ avalanche triggers across the slope. He quickly skis to a safe area avoiding the danger, but has to watch as the avalanche picks up speed before ____________ making its way to the parking lot, gradually destroying his truck.

9. Stability Test (5 pts)

You have just dug a pit up at Guardsman Pass and you have some concerns about the stability of the snowpack after looking at hand hardness, grain type, and considering the data you have been tracking on the weather timeline. You decide to do two stability tests, the extended column test and the trapezoid test. Describe how to carry out these tests, the fundamental difference between the two, and how arrive at and interpret the results of each test