Midterm Examination

Name	Student #
Signature	*for marking only* Marks Grade

Write answers directly into the space provided. Additional pages are not allowed and will not be marked. There are 8 pages. Make sure you have all. Marks are indicated in square brackets. Total possible marks are 100 (Part A: 32, Part B: 28, Part C: 40). Time allowed - 80 min.

Part A: Multiple choice questions

Solve <u>all</u> multiple choice questions. Check only one box per question. If you check none or multiple boxes, your answer will be invalid and you receive zero points.

1. In which of the following times is the Sun always at its highest point at noon (12:00) in Montreal? [4]

   ○ LMST   ○ PST   ○ UTC   ○ LAT

2. Which is the most dominant energy transfer process in well drained soils? [4]

   ○ Conduction   ○ Convection   ○ Latent heat   ○ Radiation

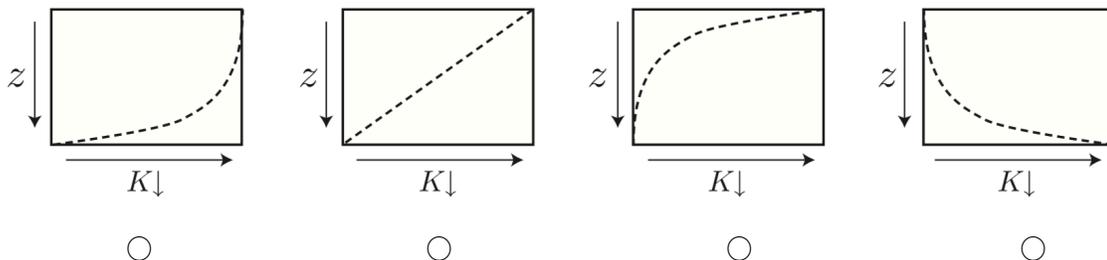3. How is net long-wave radiation defined? [4]

   ○ $L\uparrow/L\downarrow$ ○ $\varepsilon_o L\downarrow -\varepsilon_o\sigma T_o^4$ ○ $(1-\alpha)L\downarrow$ ○ $L\downarrow(1-\varepsilon_o)+\varepsilon_o\sigma T_o^4$

4. Which of the following soils has the lowest thermal diffusivity κ [4]
   ○ A soil with $k = 0.1$ W m^{-1} K^{-1} and C = 4 MJ m^{-3} K^{-1}
   ○ A soil with $k = 0.1$ W m^{-1} K^{-1} and C = 0.25 MJ m^{-3} K^{-1}
   ○ A soil with $k = 1$ W m^{-1} K^{-1} and C = 4 MJ m^{-3} K^{-1}
   ○ A soil with $k = 1$ W m^{-1} K^{-1} and C = 0.25 MJ m^{-3} K^{-1}

5. How does K↓ change with depth z in a lake? [4]
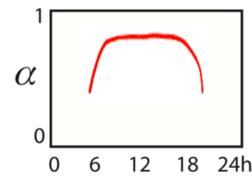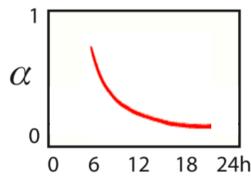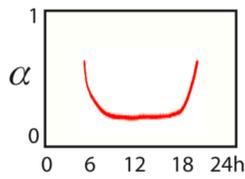

   ○   ○   ○   ○

6. What is the dominant cause for the production of turbulence over an array of buildings at night? [4]

   ○ Isotropy   ○ Sensible heat   ○ Form drag   ○ Thermal admittance

7. For Montreal, how do you expect the albedo of an open water surface to change over a clear-sky day? [4]

     ○   ○   ○   ○
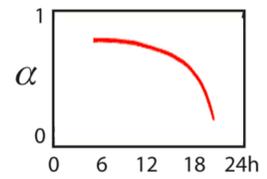
8. Which statement about the laminar boundary layer (LBL) thickness is correct? [4]
   - ○ The LBL thickness shrinks with increasing object size.
   - ○ The LBL thickness increases with increasing wind speed.
   - ○ The LBL thickness shrinks with increasing buoyancy.
   - ○ The LBL thickness increases with increasing roughness of the surface.

Part B: Short answer questions.

Answer only four out of these five short answer questions. Note: the first four questions with any answer written into the space provided will be marked, hence solving more than four questions is not to your advantage.

1. Briefly explain the difference between *mechanical* and *thermal* production of turbulence. [7]

2. Briefly explain the difference between the *damping depth* in a soil and *thermal admittance*. [7]

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3. Briefly explain the difference between *shortwave* and *longwave radiation*. [7]

4. Briefly describe two ways in which the *soil temperature wave* changes with depth as it moves down in response to radiative forcing at the surface, and how the *radiative flux density* changes with depth in water. [7]

5. Assuming that a surface has an emissivity $(\varepsilon_{o,LW})$ of 0.9, what is the reflectivity of the surface in the long-wave band $(\alpha_{o,LW})$ [3], and how much of the incoming long-wave radiation $(L\downarrow)$ is reflected from the surface assuming that $L\downarrow$ is 100 W m^{-2} [7]?

Part C: Problem questions

*Answer **four** out of the following five questions. 10 marks each. Again: the first four questions with any answer written into the space provided will be marked, hence solving more than four questions is not to your advantage.*

1. How do the components of the surface energy balance (i.e. Q_H, Q_E, Q_G) change after a grassland that experienced drought finally receive rain?

   (a) In the table below, compare the components of the surface energy balance. Fill-in the boxes below with ($=$,$<$, or $>$). Briefly explain each postulated change (or explain why no change is expected). [6]

Dry grassland		Wet grassland	Brief explanation
Q_H	☐	Q_H	
Q_E	☐	Q_E	
Q_G	☐	Q_G	

   (b) How would that impact the bowen ratio β (i.e. would you expect the bowen ratio to be higher, lower or stay the same and why) [2]?

   (c) Name and describe one other term in the surface energy balance that we would need to consider if the grassland were covered in snow [2]?

2. The graphs below show how soil thermal properties (i.e., C - heat capacity, k - thermal conductivity, κ - thermal diffusivity, μ - thermal admittance) vary with increasing soil water context (θ_w).
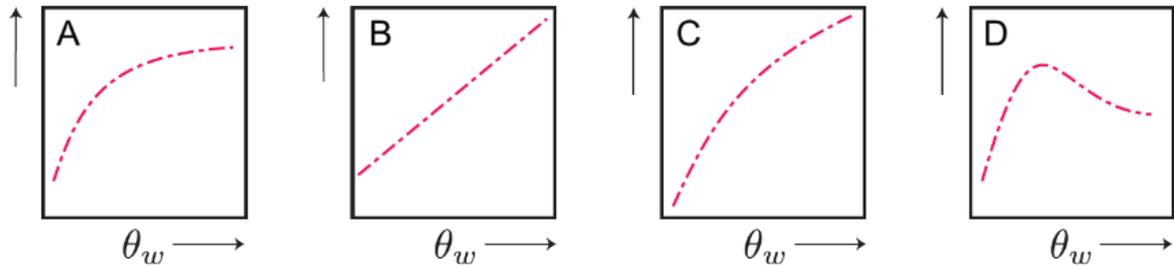
(a) Indicate which soil thermal property corresponds to each of the graphs. [4]:

(b) Briefly discuss the shape of each of the curves. [4]

(c) What is the slope of the line in B? [2]

3. Net radiation ($Q*$) can be written as:

$$K{\downarrow}(1\text{-}\alpha) + \varepsilon_o L{\downarrow} - \varepsilon_o \sigma T_o^4$$

(a) Which terms in this equation are related to surface properties? [3]

(b) Which surface properties in the net all-wave budget tend to partially offset each other? What is the implication for $Q*$? [4]

(c) Which terms are controlled by solar geometry and the atmosphere? How do clouds impact these terms? [3]

4. In class, we discussed the spectral reflectivity of leaves and how we can use this information in remote sensing applications. Below are two spectra, one is from a green leaf and one is from an autumn leaf.
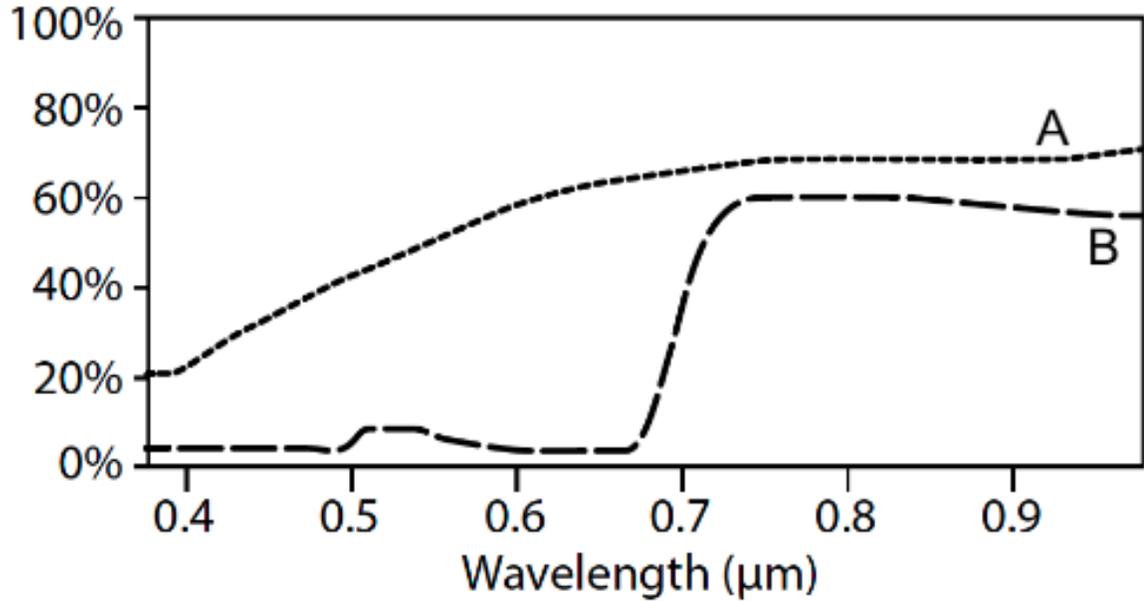

(a) How would you label the y-axis of the graph? [1]

(b) Identify which wavelengths along the x-axis correspond to visible (VIS) and near infrared (NIR) portion of the electromagnetic spectrum. Also, which wavelengths correspond to Photosynthetically active radiation (PAR)? [3]

(c) Attribute the green and autumn leaf to the corresponding curves (A or B), and briefly justify your choice. [2]

(d) Briefly say how the difference in the curves may benefit the remote sensing of land surfaces. Would the green or autumn leaf have a greater normalized difference vegetation index (i.e., NDVI)? Briefly justify your choice. [4]

5. The graph below shows the daily totals of all four components of the radiation balance measured at a research station over the course of a year.
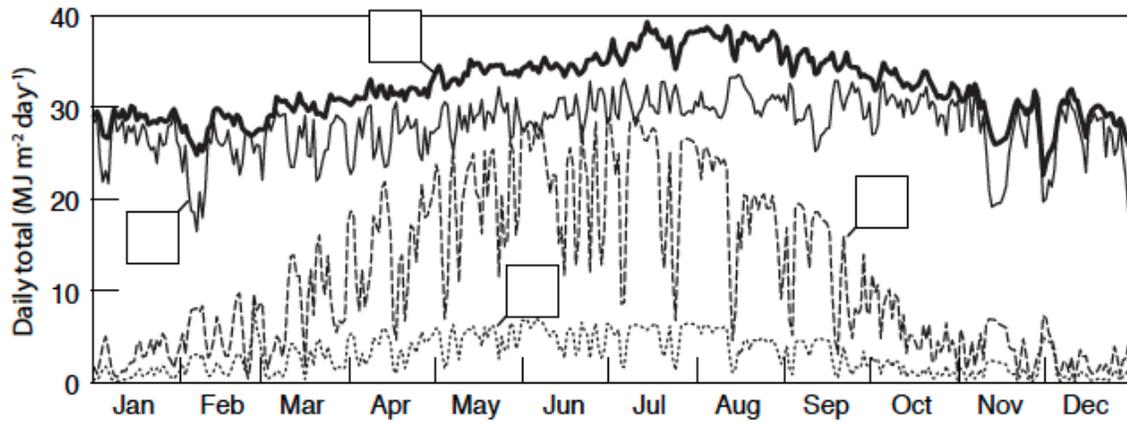
(a) Fill in the boxes with the name of the appropriate radiant flux densities, and justify your choice. [6]

(b) What are the instruments that measure each of the components? [2]

(c) When during the year (month), is Q* most negative? When is it most positive? [2]