McGill University
Knox / GEOG 321 / February 29, 2024

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 7 pages. Make sure you have all. Marks are indicated in square brackets. Total possible marks are 102 (Part A: 36, Part B: 24, Part C: 42). Time allowed - 80 min.

Part A: Multiple choice questions

Solve all 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 ◯ EST ◯ LAT ◯ UTC

2. Which layer of the atmosphere is primarily influenced by the Earth's surface? [4]

   ◯ Stratosphere ◯ Mesosphere ◯ Troposphere ◯ Thermosphere

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. A researcher is studying two different surfaces: a dry, sandy desert and a wet, vegetated field. On a particular day, the net radiation (Q*) for both surfaces is the same. The sensible heat flux (Q_H) for the desert is 200 W m^{-2}, and the latent heat flux (Q_E) for the field is 150 W m^{-2}. Which of the following statements is true regarding the Bowen ratios (β) of the two surfaces? [4]

   ◯ The Bowen ratio for the desert is higher than that for the field because the desert has a higher sensible heat flux.
   ◯ The Bowen ratio for the field is higher than that for the desert because the field has a higher latent heat flux.
   ◯ The Bowen ratios for both surfaces are equal because the net radiation is the same.
   ◯ The Bowen ratio for the desert is lower than that for the field because the desert has a lower latent heat flux.

5. Which of the following is NOT a mode of energy transport in the Earth-Atmosphere system? [4]

   ◯ Conduction ◯ Convection ◯ Reflection ◯ Radiation

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. Consider two different surfaces: a snow-covered field and a dense forest. The snow-covered field has a high albedo, while the dense forest has a low albedo. If both surfaces receive the same amount of incoming solar radiation, which of the following statements is true regarding the net shortwave radiation (K*) received by each surface? [4]

   ◯ The net shortwave radiation received by the snow-covered field is higher than that received by the dense forest.
   ◯ The net shortwave radiation received by the dense forest is higher than that received by the snow-covered field.
   ◯ The net shortwave radiation received by both surfaces is the same because the incoming solar radiation is equal.
   ◯ The net shortwave radiation received by the snow-covered field is equal to the reflected shortwave radiation from the dense forest.

8. What characterizes the flow within the laminar boundary layer (LBL)? [4]
   ◯ Turbulent flow with eddies.
   ◯ Smooth flow with parallel streamlines.
   ◯ Chaotic flow with cross-stream components.
   ◯ Random flow with no distinct layers.

9. Reynolds averaging is a technique used in fluid dynamics to separate the instantaneous measured velocity into mean and fluctuating components. Given the instantaneous velocity u, it can be expressed as:

$$u = \overline{u} + u'$$

   where $\overline{u}$ is the mean velocity and u' is the fluctuating component.

   Which of the following statements is true? [4]

   ◯ The mean of the fluctuating component u' over time is zero.
   ◯ The mean of the fluctuating component u' over time is equal to the mean velocity $\overline{u}$.
   ◯ The mean velocity $\overline{u}$ is always greater than the fluctuating component u'.
   ◯ The fluctuating component u' is always positive.

Part B: Short answer questions.

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

1. Briefly describe the concept of *thermal admittance* and its relationship to other soil thermal properties. Don't forget to include the units of thermal admittance. Briefly explain its significance in soil temperature variations. [8]

2. Identify and briefly describe the *four* main components of the *surface energy balance equation.* Also, indicate the units of each of the terms. [8]

3. Briefly describe the factors that contribute to the *mechanical* production of turbulence in the atmospheric boundary layer. [8]

4. Assuming that a surface has an emissivity ($\varepsilon_{o,LW}$) of 0.8, what is the absorptivity of the surface in the long-wave band ($\zeta_{o,LW}$), 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} [8]?

Part C: Problem questions

*Answer **three** out of the following four questions. 14 marks each. Again: the first three questions with any answer written into the space provided will be marked, hence solving more than three questions is not to your advantage.*

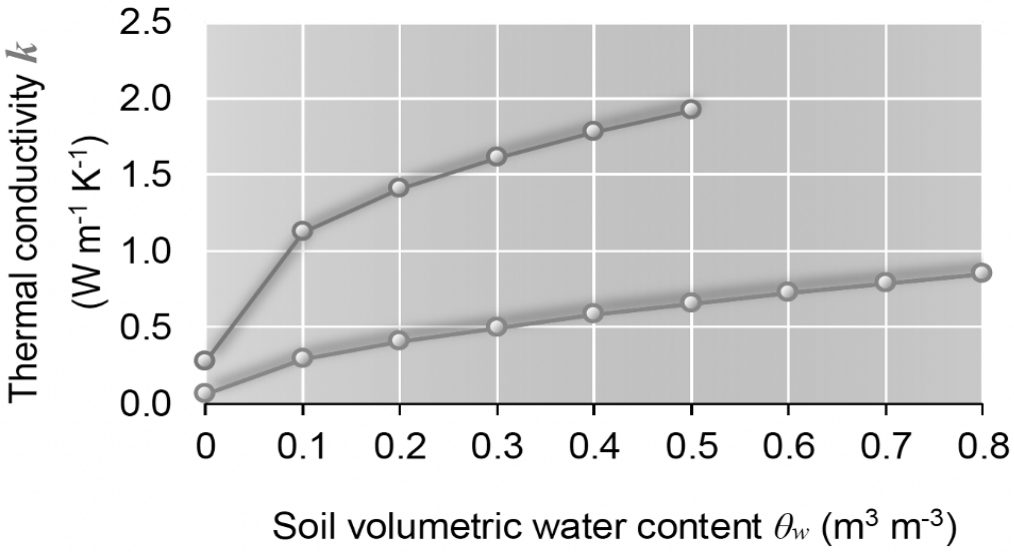
1. How do the components of the surface energy balance (i.e. Q_H, Q_E, Q_G) change after a forest that experienced drought finally receives rain?

   (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). [9]

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 [5]?

2. The graphs below shows how soil thermal conductivity (k) varies with increasing soil water content for a *mineral* and an *organic* soil (θ_w).



(a) Indicate which line correcponds to the mineral soil and which one corresponds to the organic soil. Note that you can label them directly on the graph. [4]

(b) Justify your answer in (a). [6]

(c) Briefly discuss and explain the relationship between k and θ_w. [4]

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

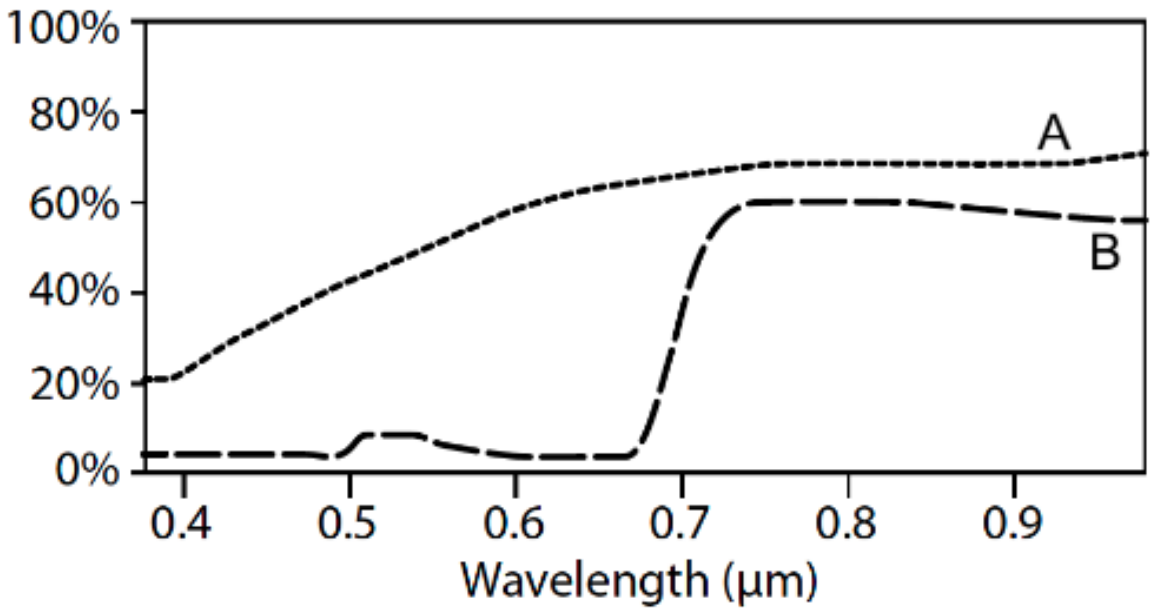
$$K\downarrow(1\text{-}\alpha) + \varepsilon_o L\downarrow - \varepsilon_o \sigma T_o^4$$

(a) Which terms in this equation are related to surface properties? [6]

(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? [4]

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? [2]

(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. [3]

(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. [6]

END OF EXAM