Answer Key - Midterm Examination 2011

Part A: Multiple choice questions

1. *What is the property that describes the energy required to warm up one kilogram of air by one Kelvin? [4]*

   ⊗ The specific heat of air c
   ◯ The thermal diffusivity of air κ
   ◯ The heat capacity of air C
   ◯ The thermal admittance of air μ

   → See Lecture 11, slide 5.

2. *What is the correct definition of 'albedo' α? [4]*

   ◯ The radiant flux density (in $\mathrm{W\,m^{-2}}$) reflected by a surface.
   ⊗ The reflection coefficient (in %) of a surface in the entire shortwave part of the spectrum.
   ◯ The average reflectance (in $\mathrm{W\,m^{-2}}$) of a surface in the entire shortwave part of the spectrum.
   ◯ The average reflectivity (in %) of a surface in the shortwave part of the spectrum.

   → See Lecture 6, slide 3.

3. *Which statement is <u>always</u> valid for a horizontal land-surface? [4]*

   ◯ $Q^* \geq 0$ ⊗ $K^* \geq 0$ ◯ $L^* \leq 0$ ◯ $L^* \geq 0$

   → See Lecture 9, slides 3 and 4.

4. *Which of the following relationships is <u>incorrect</u>? S is direct beam irradiance, D is diffuse irradiance. [4]*

   ◯ $S \leq K_\downarrow$ ◯ $D \leq K_\downarrow$ ⊗ $K_\uparrow \leq K_\downarrow - S$ ◯ $K_\uparrow \leq S + D$

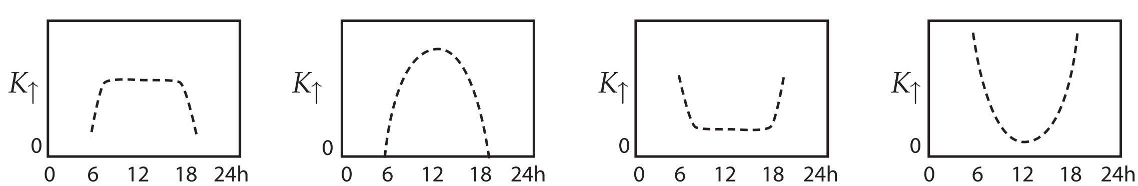
   → See Lecture 5, slides 12 to 14.

5. *For Vancouver (123° W, 49° N), in which reference time does solar elevation β <u>always</u> reach it highest point on each day at 12:00 (noon)? [4]*

   ⊗ LAT ◯ LMST ◯ PDT ◯ None

   → See Lecture 4, slide 10.

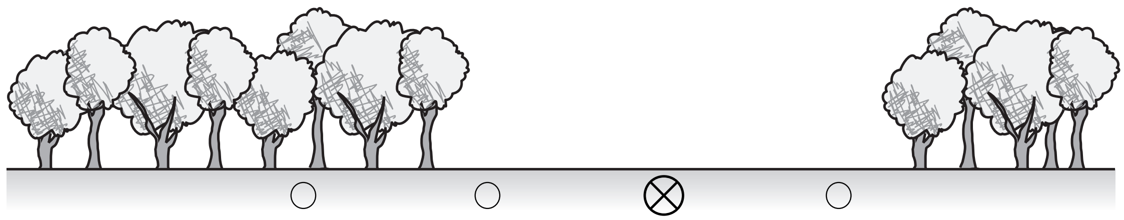
6. *In British Columbia, how do you expect the short-wave reflectance $K_\uparrow$ of a grass surface - such as Totem Field - to change over a clear-sky day? [4]*



   ◯ ⊗ ◯ ◯

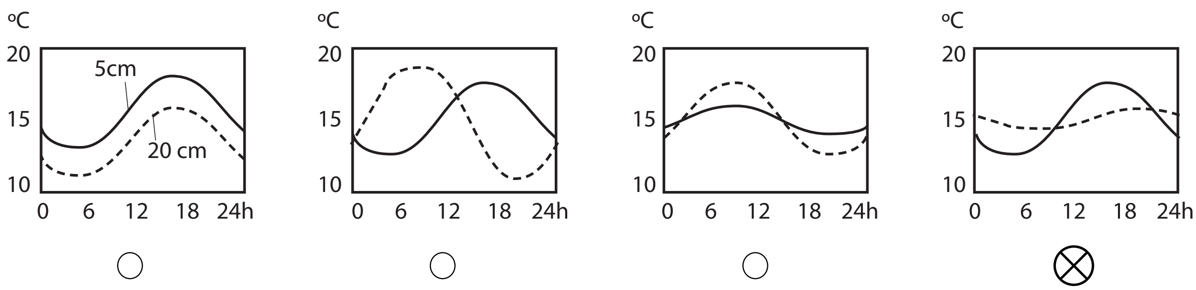
   → See Lecture 6, slide 8 and assignment 1.

7. *This sketch shows a cross-section through a dense forest and a clearing. For a night situation without any clouds, where on the ground would you expect the lowest (most negative) Q^*?. Assume that ground and tree temperature is about 10° C, and air/sky temperature is lower. [4]*



→ See Lecture 7, slide 19 and Lecture 9.

8. *Which of the following graphs shows realistic soil temperature traces at a depth of 5 cm (full line) and at a depth of 20 cm (dashed line) for a typical soil in mid-summer in British Columbia? [4]*



→ See Lecture 13, slide 12.

Part B: Short answer questions.

1. *Briefly explain the difference between the Solar constant I_0 and the Extraterrestrial irradiance K_{Ex}. [7]*

The solar constant I_0 is the average short-wave radiant flux density at the top of the atmosphere [1], normal to the solar beam [2], at Earth's mean distance from Sun [1].

The extraterrestrial irradiance K_{Ex} is the actual short-wave radiant flux density at the top of the atmosphere [1] (i.e. taking into account the actual changing distance Sun-Earth), received on a sloped surface parallel to the land surface at a given latitude [2][1,2]

→ See Lecture 4, slide 19.

2. *Briefly explain the difference between Reflection and Emission. [7]*

Reflection is the process in which incident radiant energy is returned back where it originated [4], while emission is the process in which an object or surface actively releases radiant energy. [3]

→ See Lecture 5, slide 3.

3. *Briefly explain the difference between Resolution and Domain of an atmospheric model. [7]*

The resolution is the level of detail[3] in space and time that is modelled such as the grid spacing of a discrete model. [4]

The domain of a model is the area (or volume) and total period represented in a model. [3]

→ See Lecture 2, slide 5.

4. *Briefly explain the difference between the bulk Atmospheric transmissivity and the Atmospheric window. [7]*

   Atmospheric transmissivity is the relative fraction of the (extraterrestrial, short-wave) irradiance (or generally of radiation in a particular wavelength λ) that is transmitted through the atmosphere. [3]

   The atmospheric window is a *region*[4] of the electromagnetic spectrum [1], specifically in the long-wave band between 8 μm and 13 μm [1], where the absorption by atmospheric gases is weak and the dry atmosphere is mostly transparent [2].

   → See Lecture 5, slides 19/20 and Lecture 8, slide 8.

5. *Calculate the heat capacity C_{soil} of a dry mineral soil with a porosity of 50%. The heat capacity of the mineral soil matrix is $C_m = 2.0\,\mathrm{MJ\,m^{-3}\,K^{-1}}$. [7]*

   The compound heat capacity for a soil is given by[5]

$$C_{soil} = C_m \times \theta_m + C_a \times \theta_a$$

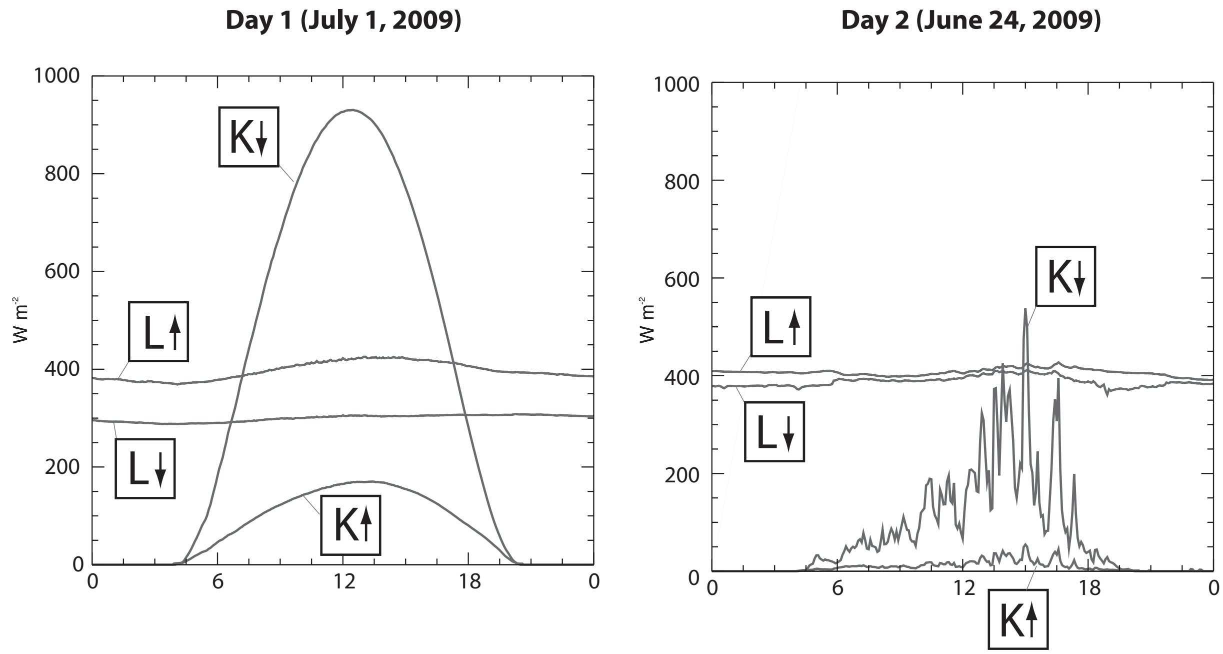
   Where C_a is three orders of magnitude smaller than C_m so the second term can be neglected. Because it is a dry soil, $\theta_a = P = 0.5$ and $\theta_m = 1 - P = 0.5$ [2]

$$C_{soil} = C_m \times \theta_m = 2.0\,\mathrm{MJ\,m^{-3}\,K^{-1}} \times 0.5 = \underline{1.0\,\mathrm{MJ\,m^{-3}\,K^{-1}}}[5]$$

   → See example in reading package L11-13, page 2.

Part C: Problem questions

1. *The following two graphs show all four components of the radiation balance on Totem Field for two summer days. (a) Label all curves on both days with the correct symbols ($K_\uparrow$,$K_\downarrow$,$L_\uparrow$,$L_\downarrow$) (b) What can you say about the weather on those two days? (c) Which day has the higher daily total Q^*, which has the higher daily total K^* and which has the higher daily total L^*? Briefly justify your choice (a few words each is enough) [10]*



(a) Correct labels as shown above return [4] marks [0.5 marks each]

(b) Day 1 is a clear (or cloudless) day, day 2 is an overcast day (or a day with clouds / fog). [2]

(c) Daily total of K^* is <u>greater on day 1</u>. This is because there is more $K_\downarrow$ in absence of clouds[6]. [1]

Daily total of L^* is <u>greater on day 2</u> (or: less negative)[7]. This is because $L_\downarrow$ in absence of clouds is lower than with clouds (colder apparent sky temperature vs. warmer cloud base temperature)[8]. [1]

Daily total of Q^* is <u>greater on day 1</u>. ($Q^* = K^* + L^*$). Although we loose more in L^* on Day 1, there is much more input in K^*. [2]

→ See Lecture 9, slides 14-15

2. *Compare the same bare mineral soil in a dry and a saturated state. (a) Which state has a higher thermal conductivity k? Justify your answer. (b) Which state has a higher thermal admittance μ? Justify your answer. (c) Which state has the higher albedo? Justify your answer. [10]*

(a) The wet soil has a higher thermal conductivity k [2], the contact area between soil grains is increased when water is present (air is a poor conductor). [1].

(b) The wet soil has a higher thermal admittance μ [2]. $\mu = \sqrt{C\,k}$, and both, k (see (a)) and C are higher if water is replacing air ($C_a << C_w$) [2].

(c) The dry soil has a higher albedo α [2]. Wetting the soil causes water to absorb radiation efficiently in all wave-lengths (mostly in the NIR) [1].

→ See Lecture 11, slides 15/18 and Lecture 6, slide 5

3. *You saw the following meteorological instrument on UBC Totem Field during the field visit. (a) What is the name of the instrument? (b) Which meteorological process or variable does it measure? (c) How does it work? [10]*

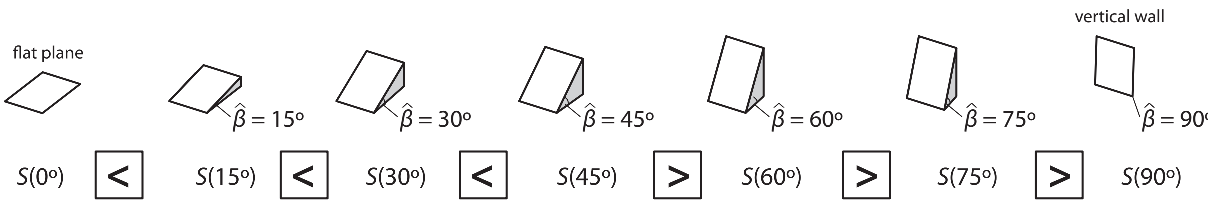
(a) This is a 'net radiometer'[9] [3]

(b) It measures net [1] all-wave [1] radiation [1][10]

(c) There are two absorber disks, one on top (responds to upper hemisphere), one on the bottom (responds to lower hemisphere) that absorb radiation in all wave-lengths and convert radiative energy to heat [2]. The sensor measures the *temperature difference between the upper and lower disk*, which is proportional to the net all-wave radiation. [2]

→ See Reading Package L10 / Field visit.

4. *All of the following slopes are oriented towards South ($\hat{\Omega} = 180°$), but have different slope angles $\hat{\beta}$.*
(a) Assume those slopes are located at the latitude of $\phi = 45°$N, and disregard any effects of the atmosphere (clouds etc). $S(\hat{\beta})$ is the annual total direct-beam irradiance for each of the slopes. Fill in the boxes with either '>', '<', or '=', i.e. compare $S(0°)$ with $S(15°)$ and write in the box between $S(0°)$ and $S(15°)$ if $S(0°) < S(15°)$, $S(0°) > S(15°)$, or $S(15°)$ if $S(0°) = S(15°)$. Repeat the same for all other boxes.

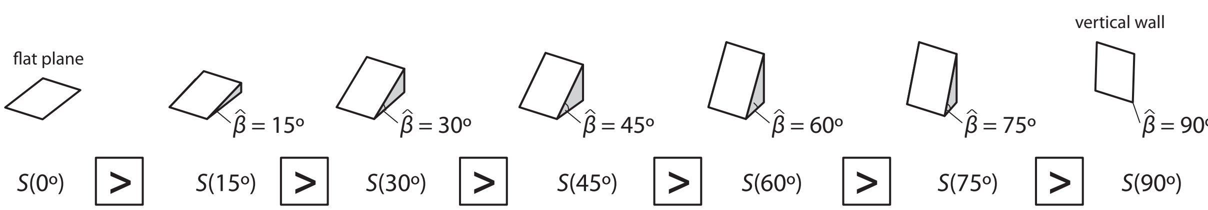


The correct symbols give in total [3] marks. [for each correct symbol 0.5 marks]

(b) How is $S(15°)$ and $S(75°)$ distributed over the course of a year?

$S(15°)$ peaks in summer (sun high above horizon), and $S(75°)$ peaks in winter (sun closer to horizon) - explained by cosine law.

(c) How would your answer to (a) differ if you are not at $\phi = 45°$N but at the Equator (and the slope is still oriented towards South ($\hat{\Omega} = 180°$)? [10]

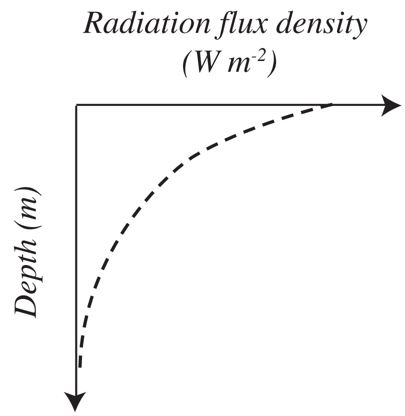


The correct symbols give in total [3] marks. [for each correct symbol 0.5 marks]

→ See Lecture 15, classroom hand-out.

5. *Shortwave radiation can be transmitted through the upper layers of a snow-pack. (a) Sketch the form of the decay of radiation with depth beneath the surface. (b) say how it differs with wavelength (in the short-wave). (c) What is the name of the law used to describe the curve? [10]*

(a)



[1 mark for correct axes, 3 marks for exponential decay]

(b) The extinction coefficient k is low in the blue part of the visible spectrum and increases towards red and ne
[3]

(c) This is Beer's Law[12] [3]

→ See Lecture 14, slides 5, 6 and 13.

6. *The following figure shows Vancouver from space. The figure visualizes radiation measured between $\lambda = 8\mu$m and $\lambda = 13\mu$m by a satellite sensor. (a) Describe why the satellite measures exactly in this range of the electromagnetic spectrum. (b) What does the map actually show (i.e. which physical processes are causing the signal)? [10]*

The satellite measures in this range because this is the atmospheric window [2] in the long-wave part of the spectrum. In this range a cloudless atmosphere is quite transparent, as only a few trace gases absorb radiation [2]. This allows us to see the surface, and not the intervening atmosphere. [1]

The map shows the long-wave [1] emittance[13] [2] and reflectance[14] [2] of the land and ocean surface.[15]

→ This map has been discussed in Lecture 7, on slide 6

Notes

[1]You can alternatively say: Received by a land surface in absence of any atmospheric effects [3]

[2]You can also write for K_{Ex}: $K_{Ex} = I_0 \left(\frac{R_{av}}{R}\right)^2 \cos Z$

[3]Can also say: smallest resolved phenomena

[4]Can also say: range, band, subset etc.

[5]This equation is not required for full marks. Essentially you only need the last equation and the result to get [7] marks.

[6]You can also say: Area between the two curves $K_\downarrow$ and $K_\uparrow$ is larger on Day 1

[7]You can also say: Daily total of L^* is more negative on day 1

[8]You can also say: Area between the two curves $L_\downarrow$ and $L_\uparrow$ is larger (more negative) on Day 1

[9]Or: 'net all-wave radiometer' (although unusual term)

[10]Alternatively you can say it measures Q^* [3]

[11]You can also say: The transmissivity is high in the blue part of the visible spectrum and decreases towards red and near infrared.

[12]Can also say Beer-Lambert's Law

[13]Can also say 'emission'

[14]Can also say 'reflectance'

[15]You can also say the map shows the surface temperature T_0 which can be calculated from longwave emittance using the Stefan-Boltzmann law.