

Answer Key - Sessional Examination

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|-----------|----------------------------------|-------|
| Name | Student # | |
| Signature | <i>for marking only</i> Marks | Grade |

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. Total: 24 marks (24% of exam).

1. Name the ratio $K_{\uparrow}/K_{\downarrow}$? [2]

- Albedo Net all-wave radiation Net short-wave radiation Reciprocal of albedo

2. Which expression describes the sensible heat flux density Q_H ? [2]

- $\rho_a c_p \overline{w'T'}$ $\rho_a C_a \partial\theta/\partial z$ $c_p L_v \partial T/\partial z$ $C_p L_v \overline{w'\rho'_v}$

3. Which dimensionless number is used to determine whether a flow is laminar or turbulent? [2]

- Reynolds number Knudsen number Obukhov number Richardson number

4. What is ‘extraterrestrial irradiance’? [2]

- The total cosmic background radiation reaching Earth in W from outside our solar system.
 Radiative flux density in W m^{-2} reaching Earth’s surface that comes from all non-terrestrial sources.
 Short-wave radiant flux density in W m^{-2} received at the top of the Earth’s atmosphere from the Sun.
 Total short-wave radiant flux emitted by the sun in W.

5. Which term describes the standard deviation of turbulent temperature variations T ? [2]

- $\overline{(\sqrt{T'})}$ $\sqrt{\overline{T'^2}}$ $\sqrt{\overline{T'}^2}$ $\sqrt{\overline{T}^2}$

6. UBC researchers have installed the following instrumentation above a forest clear-cut. What is this? [2]

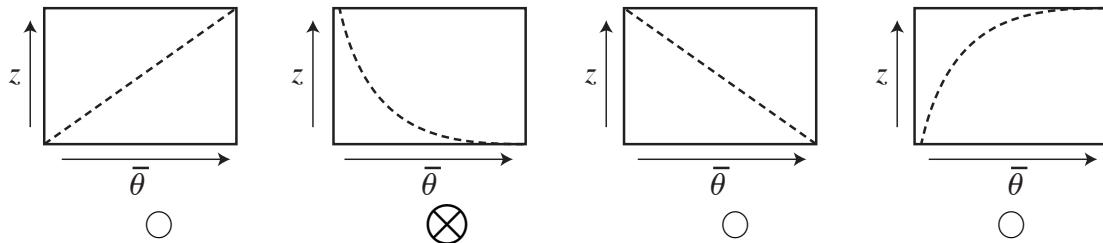
- Eddy-covariance system Lysimeter Interceptor Penman-Monteith Apparatus



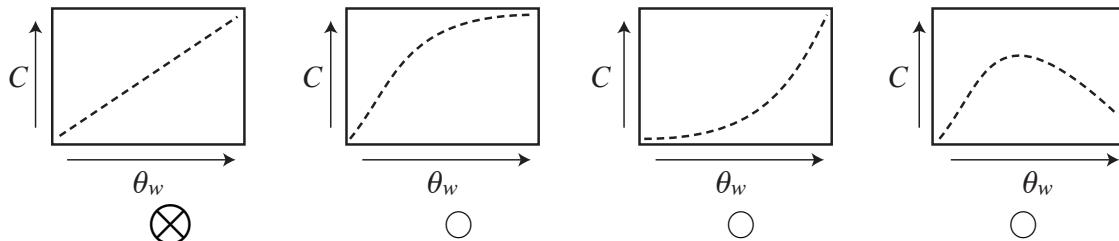
7. Which of the following terms can the instrumentation shown on the photo not measure? [2]

Q^* Q_E Q_H τ

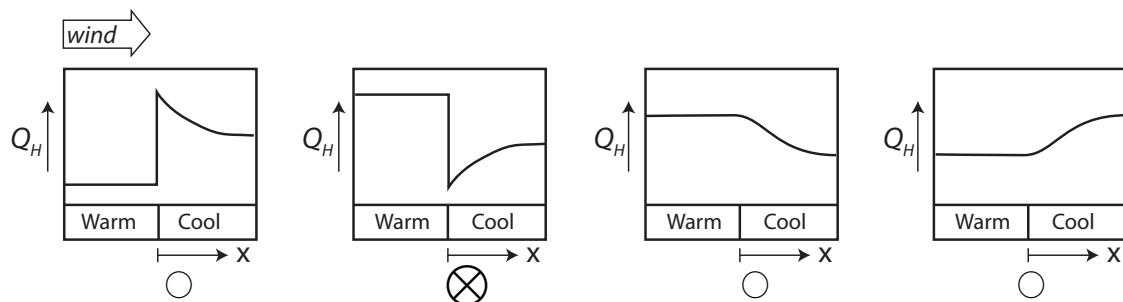
8. How does potential temperature θ change with height z in the lowest 100 m above ground on a sunny day? [2]



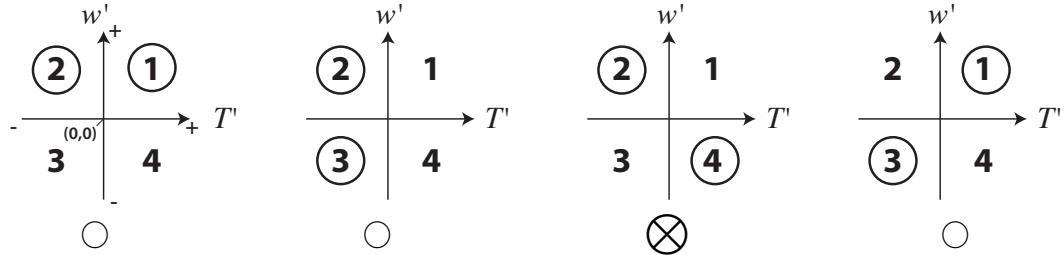
9. How does soil heat capacity C change with increasing soil volumetric water content θ_w . [2]



10. How does Q_H at a height of 1 m above the surface change as an air mass flows first over a warm patch then over a cool patch? Wind is blowing from left to right, and x is the 'fetch'. [2]



11. Above a bare soil, which two quadrants (combinations) of the joint probability distribution between vertical wind w' and air temperature fluctuation T' are the two most likely ones to occur in the late evening (after sunset)? Assume clear-skies. [2]



12. Which statement on turbulent kinetic energy (TKE) is generally true in the surface layer, if everything else is kept constant? [2]

- TKE decreases with increasing net all-wave radiation.
- TKE decreases with increasing surface roughness.
- TKE decreases with increasing wind speed.
- TKE decreases with increasing stability.

Part B: One-word questions

Answer all of the following short answer questions in one or a few words, or provide a formula.
Total: 16 marks (16% of exam).

1. Name a term of your choice that is part of the water balance equation for a land surface. [2]
Any of the following: Precipitation, Evapotranspiration (Evaporation, Transpiration), Run-off, Drainage, Soil water change (Storage change).
2. What does 'PAR' stand for? [2]
Photosynthetically active radiation
3. Write out the name of the variable u_* . [2]
Friction velocity
4. Name an instrument of your choice that measures shortwave radiation. [2]
Any of the following: Pyranometer, Diffusometer, Pyrheliometer, (also count: Net-radiometer)
5. Name an approach that is used to model directly or indirectly turbulence in the atmosphere. [2]
Any of the following: DNS (Direct numerical simulation), LES (Large eddy simulation), RANS (Reynolds averaged Navier Stokes). Abbreviation or full text is OK.
6. List an atmospheric variable of your choice that controls stomatal aperture. [2]
Any of the following: PAR, Air Temperature, vpd (or vdd, relative humidity), CO₂ concentration in stomatal cavity, Cell water pressure (turgor).
7. List a method of your choice that can be used to measure evapotranspiration of a crop. [2]
Any of the following: Eddy covariance, Lysimetry, Penman-Monteith (or combination model), Aerodynamic approach, Bowen ratio-energy balance approach, Monin-Obukhov similarity. DO not count: Porometry, Sap flow, Pan evaporation.
8. Name the amount of precipitation (in mm) in a canopy that does not reach the ground, but remains on the canopy structure (leaves, branches etc.) [2]
Interception

Part C: Short answer questions

1. Briefly explain the difference between the energy balance and the energy cascade. [5]

The energy balance accounts for all energy fluxes [1] (more precisely: flux densities) that reach or leave a surface¹. It is a statement² that energy is conserved³ [1].

The energy cascade is the process of large eddies [1], produced by shear and buoyancy, breaking up in smaller ones [1] that eventually dissipate [1] to heat.

2. Briefly explain the difference between a turbulent and a laminar flow. [5]

In a turbulent flow the streamlines are curved and (quasi) random [2]. Mixing is very effective by convection [1].

In a laminar flow streamlines are roughly parallel [1] to each other⁴, and exchange is only achieved by molecular processes [1]⁵

3. Briefly explain the difference between photosynthesis and transpiration. [5]

Photosynthesis is the process where plants take up CO₂ through the stomata [2] and convert it to carbohydrates ⁶ [1].

Transpiration is the process where plants lose water through the stomata to the atmosphere [1].

4. Briefly explain the difference between eddy diffusivity and molecular diffusivity for sensible heat.[5]

The eddy diffusivity for sensible heat relates the gradient of temperature [1] ($\partial\theta/\partial z$) to the sensible heat flux density [1] (Q_H) when there is convection [1] ⁷.

The molecular diffusivity also relates a gradient to the sensible heat flux density, but under conditions when heat is only conducted [2] by molecular processes ⁸

5. Briefly explain the difference between form drag and skin drag. [5]

Form drag is the drag that arises due to dynamic pressure differences [2] between windward and lee-side of an obstacle [1] (e.g. rock, building, tree) in a flow.

Skin drag is the drag a surface imposes due to the no-slip condition at the interface [2] ⁹. Skin drag can happen over a flat surface.

6. Briefly explain the difference between the roughness length and the Obukhov length. [5]

The roughness length is the integration constant¹⁰ [1] of the logarithmic wind profile [1] and is a measure for the aerodynamic roughness of a surface [1]

The Obukhov length is a measure for the dynamic stability of the atmosphere¹¹ [2] (Not needed but good: It is interpreted as the height above ground where buoyancy and shear production of TKE are equal).

Notes

¹Instead of surface students can also say: system, leaf, animal, human or air parcel

²also: equation

³can also state equation: $Q^* = Q_H + Q_E + Q_G$ to get full marks [2].

⁴or layers glide by, no mixing etc.

⁵can also say (molecular) diffusion, or conduction.

⁶Instead of carbohydrates can also say use it for plant tissue, plant growth etc.

⁷Can also say: turbulence

⁸Can alternatively say: Constant of proportionality in Fourier's law

⁹Can also say due to the fact that air molecules are attached to the surface or equivalent

¹⁰Can also simply say a term of the logarithmic wind profile equation

¹¹surface layer