You are allowed ten minutes before the start of the examination to acquaint yourself with the instructions below and to read the question paper.

Do not write anything until the invigilator informs you that you may start the examination. You will be given five minutes at the end of the examination to complete the front of any answer books used.

April 2001 **DE 0567**

Data Sheet
Figs. 1a and 1b for Q2
Fig. 2 for Q3
1 x Answer Book
Calculators are permitted

THE UNIVERSITY OF READING

MSc/Diploma
Course in Applied Meteorology
Course in Weather Climate and Modelling

MRes Course in
Earth and Atmospheric Science

PAPER MTB50

Boundary Layer Meteorology and Micrometeorology

One and a half hours

Answer QUESTION 1 and **either** question 2 **or** question 3

The marks for the individual components of each question are given in [ ] brackets. The total mark for the paper is 100.

A foreign language dictionary can be used by those students whose first language is not English.

1. (a) Describe the physical processes that distinguish (i) atmospheric boundary layer from the free atmosphere, (b) the surface layer from the boundary layer.

[5 marks]

(b) Describe, using a sketch diagram and with typical values of parameters, the diurnal evolution of the boundary layer in mid-latitudes.

[10 marks]

(c) Explain, with equations and stating clearly any assumptions you make, how Monin-Obukhov scaling can be used to obtain the variation of mean wind and potential temperature in a stably and unstably stratified surface layer.

[20 marks]

(d) Describe the dynamical and chemical processes that control the concentration of ozone near the ground over a diurnal cycle of a polluted boundary layer.

[15 marks]

2. (a) Fig. 1 shows measurements of the components of the surface energy budget over a diurnal cycle. Fig. 1a is for an urban area and Fig 1b is for a rural area. Describe the physical processes that lead to the differences between Figs. 1a and 1b. Sketch on one graph the variation in surface temperature over the diurnal cycle corresponding to Figs. 1a and Ib, indicating typical values where possible.

[15 marks]

Question 2 continued overleaf

Question 2 cont'd.

(b) Write down typical values of the roughness length of (a) urban areas, z_{ou} and (b) rural areas z_{or} . With the aid of a sketch diagram, describe how a day time neutrally stratified boundary layer adjusts from rural to urban terrain, including a careful discussion of the *internal boundary layer*.

[15 marks]

The height of the internal boundary layer, h_i , is given by

$$h_i\{\ell n(h_i z_0)-1\}=0.6x$$

where *x* is the fetch. Estimate the fetch required for a rural boundary layer to adjust fully to an urban area.

[5 marks]

(c) Describe, with suitable sketch diagrams, how the temperature profile in a clear-sky nocturnal boundary layer develops as a rural boundary layer adjusts to an urban area.

[15 marks]

3. (a) Fig. 2 shows records of instantaneous vertical velocity and temperature measured at heights 5.66m and 22.6m above the surface in a convective boundary layer. Describe, with reference to the data in fig. 2, the large scale motions in the CBL (convective boundary layer).

[15 marks]

Question 3 continued overleaf

Question 3 cont'd.

(b) According to Carson's model, the depth of the CBL, *h*, evolves according to

$$h(t) = \left\{ \frac{2(1+2E)}{\rho c_p \gamma} \int_0^t H_0(t')\, dt' \right\}^{1/2} \qquad (1)$$

Explain the meanings of the symbols E, ρ, c_p, γ and H_0. Describe carefully the assumptions made to derive this formula, paying particular attention to the assumed temperature structure.

[12 marks]

If $H_0 = 300 Wm^{-2}$ which remains constant, $E = 0.2$, $\rho c_p = 1.2 \times 10^3 Jm^{-3}K^{-1}$ and $\gamma = 8.5 K\, km^{-1}$, calculate, using (1), the time taken for the CBL to grow to 1 km in depth.

[8 marks]

(c) Describe how the surface energy balance determines H_0. Hence explain, with reasoning, whether you expect the CBL to deepen most rapidly over dry bare soil, a water surface, or a vegetated surface.

[15 marks]

Figs 1a and 1b for Question 2

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Fig 2 for Question 3

End of Question Paper

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