Candidates are admitted to the examination room ten minutes before the start of the examination. On admission to the examination room, you are permitted 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.

January 2014 **MTMG02**

Answer Book
Data Sheet
Any bilingual English language dictionary permitted
Only Casio-fx83 calculators are permitted

UNIVERSITY OF READING

Atmospheric Physics
(MTMG02)

Two hours

Answer **ANY TWO** questions

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

Question 1

On our Reading University Atmospheric Observatory, Mike measures a surface temperature of $17°\mathrm{C}$, a surface pressure of 1020hPa, and a relative humidity of 65%.

(a) Using the tephigram, determine (i) the Lifting Condensation Level (LCL), (ii) the vapour mixing ratio, (iii) the wetbulb temperature. (hand in the tephigram with your answer book) **[8]**

(b) With reference to Normand's construction, explain why the cloud base of a convective cloud is usually at lower altitudes when the surface relative humidity is larger. **[8]**

(c) (i) What is the meaning of the term "heat capacity". (ii) What is the physical reason why is the heat capacity at constant volume is smaller than the heat capacity at constant pressure? **[8]**

The aforementioned surface parcel is lifted pseudo-adiabatically to 800hPa and then pushed back adiabatically to 1020hPa.

(d) (i) What is the total change in vapour mixing ratio at the end of this process. (ii) How much latent heating has been released (use correct units). (iii) How does this latent heating relate to the temperature change at the end of the process? **[9]**

The heat capacity at constant pressure of a saturated parcel is given by

$$c_p = c_{pd} + \frac{L^2 r_{vs}}{R_v T^2}$$

(e) State the meaning of all the symbols in this equation. Determine the specific heat capacity of a saturated parcel during typical fog conditions in mid-latitudes. **[9]**

(f) As can be seen in the above equation, the heat capacity for a saturated parcel is larger than that of an unsaturated parcel. Explain the physical reason why this is. **[8]**

Question 2

Answer each question, below, in less than three-quarters of a page. Use schematics or equations where appropriate.

(a) Explain why the moist adiabatic lapse rate becomes smaller at higher temperatures. **[10]**

(b) Explain why an atmosphere where the entropy decreases with height is unstable. **[10]**

(c) Explain why the change in internal energy of an open system is due to the flux of enthalpy. **[10]**

(d) Sate the meaning of the symbols in the first law, $\mathrm{d}u = T\,\mathrm{d}s - p\,\mathrm{d}v$, and use it to derive the Maxwell relation $(\partial T/\partial v)_s = -(\partial p/\partial s)_v$. **[10]**

(e) Explain why the surface tension increases the saturated vapour pressure around a spherical drop, compared to a flat surface. **[10]**

Question 3

In climate modeling some of the key experiments are performed with models where the surface temperature is prescribed. To examine some of the consequences this may have, we consider a surface at fixed temperature T_s with above it a single-slab black body atmosphere. The temperature of the atmosphere is denoted T_a.

(a) Give the definition of a black body. **[6]**

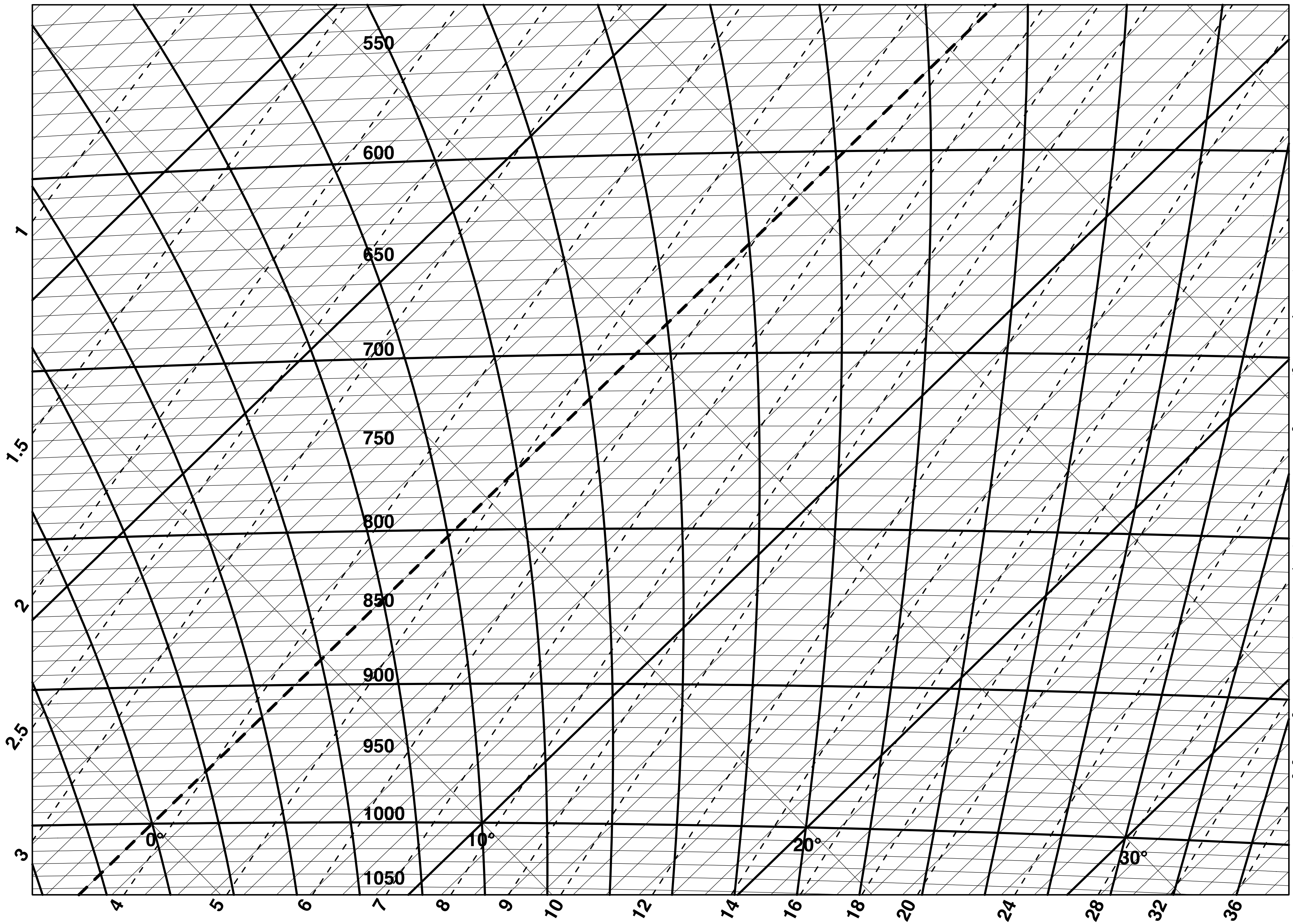
(b) (i) Draw a schematic of the situation sketched above with all the relevant radiation fluxes drawn in, (ii) write down the budget equation for the atmosphere and hence find an expression for the atmospheric temperature T_a in terms of the prescribed surface temperature T_s. (iii) What is the atmospheric temperature T_a, in degrees Celsius, if the surface temperature is $T_s = 20°\mathrm{C}$. **[14]**

(c) Explain how the surface in the climate models above can be thought of to have an infinite heat capacity. **[8]**

(d) Now assuming that there is an additional enthalpy flux between the surface and the single-slab atmosphere, explain what would happen to the temperature of the atmosphere and that of the surface. (If preferred, you can use equations to answer this question.) **[8]**

Enthalpy fluxes are normally the result of convective motion. Models parameterize such convective motion by looking at the lapse rate in the model.

(e) Assuming the single-slab atmosphere has an effective height of 5km, (i) find an expression for the lapse rate in our model. (ii) Explain whether the lapse rate increases or decreases in our model for increasing surface temperature. (iii) In reality, observed lapse rates are close to moist adiabatic lapse rates. Is our simple model realistic in its response of lapse rate to surface temperature? **[14]**



TEPHIGRAM © Maarten Ambaum, University of Reading, United Kingdom - Pressures in mbar, temperatures in °C, saturated mixing ratios in g kg^{-1}