Question 1

An air parcel has pressure 700 hPa, temperature $-4°C$, and a water vapour mixing ratio of $1\,\mathrm{g\,kg^{-1}}$. Assume the parcel is an ideal gas. You can use the tables in the data sheet provided.

a) Calculate the density of the parcel to two significant digits. **[6]**

b) If all the vapour in the parcel would condense at the same pressure level, by how much would temperature of the parcel change? **[6]**

c) Assume water vapour and dry air are ideal gases. Show that the vapour mixing ratio r_v and the vapour pressure e are approximately related as

$$e \approx \frac{\mu_d}{\mu_v} p\, r_v$$

with p the pressure, and $\mu_d/\mu_v = 1.61$ the ratio of the molar masses of dry air and water vapour. **[10]**

d) What is the relative humidity of the parcel? **[8]**

e) The differential of the specific enthalpy h is

$$dh = T\,ds + v\,dp.$$

(i) State what each symbol stands for. (ii) State the units of h. **[8]**

f) Explain in less than a half page the relevance of enthalpy to the study of open systems, systems that can exchange matter. **[12]**

(end of question 1)

Question 2

For an ideal gas, the Brunt–Vaisala frequency N is given by

$$N^2 = \frac{g}{\theta}\frac{d\theta}{dz},$$

with the potential temperature given by

$$\theta = T\left(\frac{p_0}{p}\right)^{R/c_p}.$$

a) State the definition of potential temperature **[6]**

b) Using hydrostatic balance, derive the hypsometric equation

$$Z_1 - Z_0 = \int_{p_1}^{p_0} \frac{RT}{g_0 p}\,dp$$

[8]

The table below gives two points of a sounding:

p (hPa)	T (°C)
900	7.0
700	-5.0

c) Calculate the geopotential thickness of the 900–700hPa layer, stating any assumptions you make. **[10]**

d) Using the sounding data, above, calculate the Brunt-Vaisala frequency at 800hPa, stating any assumptions you make. **[10]**

e) State the definition of equivalent potential temperature **[6]**

f) Describe the physical mechanism of potential instability. State two ways by which potential instability can be suppressed. **[10]**

(end of question 2)

Question 3

Answer each sub-question, below, in less than half a page, using equations or schematics where appropriate.

a) What is meant by the "activation radius" of a drop and what is its typical magnitude? **[10]**

b) Explain the physical mechanism by which surface tension raises the saturated vapour pressure around a curved drop? **[10]**

c) When breathing out in cold air (near 0°C) we can see condensation. Explain why this does not occur in warmer air (say, above 10°C.) **[10]**

d) State two reasons, including brief explanations, why convective available potential energy (CAPE) is an overestimate of the specific kinetic energy a parcel achieves at its level of neutral buoyancy (LNB.) **[10]**

e) Use Stefan's law to explain why the stratosphere cools on increasing its CO_2 content. **[10]**

(end of question 3)