MTMG02 Msc Atmospheric Physics exam.
Academic year 2011/2012.
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RUBRIK:
Exam duration: **three hours**.
Answer any **two out of three** questions.
Any calculator is allowed.
Any bilingual English language dictionary is allowed.
Textbooks or lecture notes are **not** allowed.

ADDITIONAL MATERIAL:
Atmospheric physics data sheet, tephigram.

Question 1

An air parcel has pressure 1000 hPa, temperature 12°C, and a relative humidity of 58%. Assume the parcel is an ideal gas. An approximate expression for the specific humidity q then is

$$q = 0.61\,\frac{e}{p}.$$

For the rest of this question you are allowed to use this approximate expression. Make use of the tables in the data sheet or the tephigram where appropriate.

a) State the difference between specific humidity and vapour mixing ratio. **[5]**

b) Calculate the specific humidity, in $\mathrm{g\,kg^{-1}}$, of the aforementioned air parcel. **[5]**

c) Determine

(i) the dewpoint temperature (in degrees Celsius)

(ii) the lifting condensation level (in hPa).

(iii) the wet bulb temperature (in degrees Celsius) **[9]**

d) Parcels are saturated when they have been cooled to their dewpoint or their wetbulb temperature. Explain why the wetbulb temperature is higher than the dewpoint temperature. **[6]**

e) We run two different experiments where we compress a cylinder adiabatically to half its volume. In the first experiment the cylinder only contains air. In the second experiment the cylinder contains air as well as some liquid water. Explain which of the two cylinders will have the higher temperature at the end of the experiment (both experiments start off at the same temperature). **[6]**

f) In a future climate we expect the warming at the poles to be about twice that at the equator, so the temperature difference between the pole and equator is expected to decrease. By assuming typical polar and equatorial surface temperatures, explain whether you expect the specific humidity difference between the pole and equator to decrease or to increase. You may assume that the relative humidity remains unchanged in a future climate. **[10]**

g) The global mean latent heat flux (that is, the upward flux of energy due to evaporation of water) is about $75\,\mathrm{W\,m^{-2}}$. From this information, derive the global mean average monthly rainfall in millimetres. **[9]**

(end of question 1)

Question 2

The specific entropy of a dry air parcel can be written as a function of temperature and specific volume as

$$s = c_v \ln(T/T_0) + R\ln(v/v_0).$$

We have assumed here that air is an ideal gas.

a) What is R in this equation, and what are its units? **[5]**

b) An air parcel of 1 litre at pressure 1000 hPa and temperature 15°C is lifted adiabatically upward by 1 km. What is the volume of the lifted air parcel? **[10]**

c) (i) Using the above equation for entropy, show that the pressure and the density of an isentropic fluid are related by

$$p = \text{constant} \times \rho^{c_p/c_v}.$$

(ii) A parcel at pressure 1000 hPa and temperature 15°C is lifted adiabatically to a pressure level of 800 hPa. What will its density be at 800 hPa? **[10]**

d) (i) In an isothermal atmosphere, at temperature T_0, derive an equation for the specific entropy as a function of height.

(ii) In light of this result, comment on the stability properties of an isothermal atmosphere. **[10]**

e) (i) What is the vertical entropy structure in a well-mixed dry boundary layer.

(ii) In a clear night the boundary layer "collapses", that is, it stabilizes rapidly. Explain why this happens and how the vertical entropy structure is modified.

(iii) The observed vertical temperature profile in the atmosphere is a balance between vertical mixing and radiative adjustment due to temperature differences. Explain whether long-wave radiation generated inside the atmosphere itself stabilizes or destabilizes a well-mixed boundary layer. **[15]**

(end of question 2)

Question 3

Beer's law gives the relation between the concentration of absorbers and the optical depth δ of a medium as

$$\delta = n\sigma l,$$

with n the number concentration by volume of absorbers, σ the absorption cross section of the absorbing molecule, and l the path length.

a) State the units of δ and of σ. **[6]**

b) A ray of radiation passes through a layer with absorbers, and 20% of the incoming radiation is transmitted.

(i) What is the optical depth of the layer?

(ii) If the concentration of absorbers is reduced by a factor 2, what percentage of the radiation is now transmitted? **[9]**

c) (i) Approximately what range of wavelengths corresponds to visible light?

(ii) How does this compare to typical sizes of haze droplets?

(iii) In this context, speculate on the visibility of individual haze droplets. **[9]**

d) Rayleigh scattering is active in the visible part of the spectrum and the associated scattering cross section is a strongly decreasing function of wavelength. Use these facts to argue why the clear sky is blue and sunsets are red. Include a relevant schematic in your answer which clarifies the two situations. **[10]**

A thin metal sheet of low heat capacity, initially at temperature of 300 K, floats in vacuum above a thick metal sheet of very high heat capacity, initially also at a temperature of 300 K. The distance between the sheets is much smaller than the distance across them. There are no further sources of radiation or heat.

e) (i) What is the temperature of the thin metal sheet when the system has reached equilibrium assuming the thick metal sheet has effectively an infinite heat capacity.

(ii) In this situation, what is the net radiation flux from the thick to the thin sheet.

(iii) What is the peak wavelength of the radiation leaving the thick metal sheet?

(iv) Now instead assuming the thick metal sheet has a finite, but high, heat capacity, comment on the expected changes in the temperatures in the system and on the equilibrium state. **[16]**

(end of question 3)