University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER I EXAMINATION 2011/2012

ACM 40490

Physical Meteorology

External examiner: Professor Peter A Clark

Head of School: Dr Patrick Murphy

Lecturer: Dr Conor Sweeney*

Time Allowed: 2 hours

Instructions for Candidates

Answer **four (4)** questions.
All questions carry equal marks.

Instructions for Invigilators

Non-programmable calculators may be used during this examination.

Question 1

(a) What are the names of the four lowest layers in the International Standard Atmosphere? Sketch the vertical temperature profile, with approximate heights and/or pressures of the different layers. Explain the reason for the temperature profile in each layer. What are the values of the temperature, pressure and lapse rate at the surface?

(b) What is Avogadro's Law? Calculate the molecular weight of dry air. Use your answer to calculate the gas constant of dry air. Similarly, calculate the gas constant of water vapour. Use the following atomic weights: H=1, N=14, O=16, Ar=40, and $R^* = 8.3145\,\mathrm{JK^{-1}mol^{-1}}$

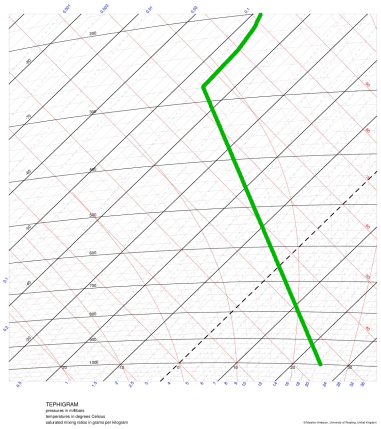
(c) What is Dalton's Law of Partial Pressures? If air at standard pressure can be considered to consist of 76% N_2, 20% O_2, 1% Ar and 3% H_2O, what is the vapour pressure?

Question 2

(a) What is an adiabatic process? Derive an expression relating the pressure and volume of an ideal gas undergoing an adiabatic process. What assumptions do we make for a parcel of air moving in the atmosphere?

(b) A hurricane with a central pressure of 940 hPa is surrounded by a region with a pressure of 1010 hPa. The storm is located over an ocean region. Assume the 200 hPa surface has uniform height. Estimate the average temperature difference between the center of the hurricane and its surroundings in the layer between the surface and 200 hPa. Assume that the mean temperature of this layer outside the hurricane is 3 °C and ignore the virtual temperature correction.

(c) What is the Clausius-Clapeyron equation? What is it used for? Estimate the temperature at which water will boil at 600 hPa. Assume the specific volume of water vapor = 1.66 $\mathrm{m^3kg^{-1}}$, the specific volume of liquid water = $1.0\times10^{-3}\,\mathrm{m^3kg^{-1}}$, and the latent heat of vaporisation = $2260\,\mathrm{kJ\,kg^{-1}}$.



(A large format copy of this figure will be provided to candidates)

Figure 1: Station sounding.

Question 3

(a) What is Normand's Rule?

(b) Describe the wet-bulb temperature, the dew point temperature, and how they differ.

(c) Readings taken at a meteorological station show that the pressure is 1000 hPa, the temperature is 25°C, and the dew point temperature is 18°C. A sounding is also taken at the same time. Use the accompanying tephigram to get the following:

- the wet-bulb temperature at the station
- the equivalent potential temperature at the station
- the LCL
- How is the CINE estimated?
- How is the CAPE estimated?

Question 4

(a) Calculate the equivalent blackbody temperature of the Earth, using the values below. How does your answer compare to the observed average surface

temperature of the Earth?
Temperature of solar photosphere = 5785 K
Radius of solar photosphere = 6.96×10^8 m
Earth-sun distance = 1.5×10^{11} m
Earth albedo = 0.30
Stefan-Boltzmann constant = $5.67 \times 10^{-8}\,\mathrm{Wm^{-2}K^{-4}}$

(b) What is a sunphotometer? Explain Langley extrapolation, stating what requirements/assumptions are made.

(c) Why does an Ozone hole form over the Antarctic during spring? Describe the different processes involved.

Question 5

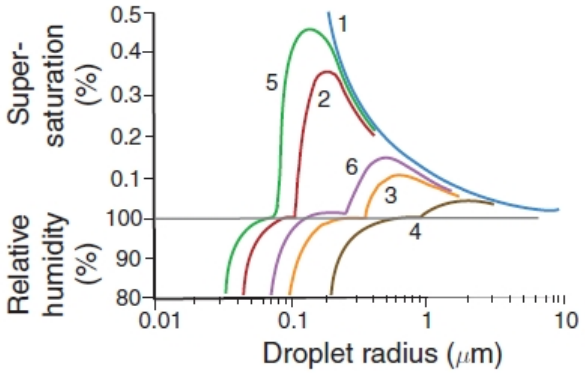


Figure 2: Köhler curves. (1) pure water, (2) 10^{-19} kg NaCl, (3) 10^{-18} kg NaCl

(a) What is homogenous nucleation? Explain why clouds observed in the atmosphere do not occur by homogenous nucleation of condensation.

(b) Use the Köhler curve in Fig.2 to describe the evolution of droplets in air with a water supersation of 0.2%, and particles of

- NaCL with mass 10^{-19} kg
- NaCL with mass 10^{-18} kg

(c) With the aid of a diagram, describe the typical evolution of the boundary layer during fair weather over land in summer.

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