Ollscoil na hÉireann, Gaillimh GX 905
National University of Ireland, Galway

Semester II Examinations, 2002/2003

Exam Code(s)	3BS9, 3BS3, 3CA3, 3EL1, 3EL2, 3ER3, 3EV1, 3EV2, 4ER2, 4EV2, 1OA1, 1EM1
Exam(s)	3rd Science
Module Code(s)	MT301
Module(s)	Introduction to the Atmosphere
Paper No.	
Repeat Paper	Special Paper
External Examiner(s)	Professor E. Kennedy
Internal Examiner(s)	Professor S. G. Jennings Dr. A. Ó Rodaighe

Instructions: Answer FIVE questions.

Duration	3 Hours
No. of Answer Books	1

Requirements:

Handout	
MCQ	
Statistical Tables	
Graph Paper	
Log Graph Paper	
Other Material	

No. of Pages	5
Department(s)	Experimental Physics

MT301 : Introduction to the Atmosphere

Q.1 Explain what is meant by the following terms:

Radiative forcing, degree Kelvin, triple point of water, planetary albedo, emissivity [4 marks]

Give a brief account of solar radiation, to include the distribution with respect to wavelength and maximum emission. Describe briefly emission of radiation from the earth's surface. [3 marks]
Hence determine the temperature at which balance occurs between incoming solar radiation and outgoing terrestrial radiation if the planetary albedo is 0.31, assuming that there are no gases present in the atmosphere and the solar irradiance at the top of the atmosphere is 1367 W m^{-2}. [2 marks]
What is the temperature if the planetary albedo decreases to 0.29? [1 mark]

Stefan-Boltzmann constant $\sigma = 5.67\ 10^{-8}$ W m^{-2} K^{-4}

Q.2 The equilibrium vapour pressure over a droplet surface depends upon its curvature and is given by $e_S(r) = e_S(\infty) \exp(2\sigma / rR_V \rho_L T)$ where $e_s(r)$ is the saturation vapour pressure over the surface of a spherical droplet of radius r with surface tension σ and density ρ_L at temperature T. R_v is the gas constant for water vapour and $e_s(\infty)$ is the saturation vapour pressure over bulk water.

(i) Define the terms saturation vapour pressure, homogeneous nucleation, critical radius and critical supersaturation. [2 Marks]

(ii) Derive an expression for the critical radius as a function of saturation ratio, $S=e/e_s(\infty)$. [3 Marks]

(iii) What is the critical radius, in micrometers, at a temperature of 7° C, for saturation ratios of 1.01 and 10? [3 Marks]

(iv) Since water saturation ratios never, or rarely, exceed 1.01, explain why homogeneous nucleation of pure water droplets does not occur in the atmosphere. [2 marks]

Physical Constants:
$\sigma = 7.5 \times 10^{-2}$ N/m, R_v=461.5 J kg^{-1} K^{-1}, ρ_L=1 g / cm^{-3} = 1000 kg m^{-3}.

Q.3 (i) Define vapour pressure, mixing ratio, specific humidity and relative humidity.

[2 Marks]

(ii) The saturation vapour pressure of water as a function of temperature is given by:

$$e_s(T) = 6.112 \exp\left(\frac{17.67T}{T + 243.5}\right)$$

Equal masses of two samples of air are thoroughly mixed and a fog is observed to form. The temperature of the first sample is 30°C and its relative humidity is 90%. The temperature of the second sample is 2°C and the relative humidity is 80%. Assuming the mixing occurs isobarically at 1000 mb and the thermodynamic properties of the mixture are mass-weighted means of their individual values, determine the temperature of the foggy air, and its liquid water content in grams per kilogram of air. The ratio of the molecular masses of water vapour to dry air is given by $m_V/m = 0.622$ [8 marks]

Q.4. Explain what is meant by the following terms:

Collision efficiency, coalescence efficiency, supercooled droplet, precipitation element.

[4 marks]

Show that a raindrop of radius R will grow at a rate given by:

$$\frac{dR}{dt} = \frac{(U-u)\omega E_{collection}}{4\rho}$$

as the drop collides with all droplets in its path. U is the fall velocity of the drop, u is the fall velocity of the cloud droplet, w is the cloud liquid water content, ρ is the density of the drop and $E_{collection}$ is the collection efficiency.

[3 marks]

A raindrop of radius 0.25 μm starts falling from cloud top through a cloud of thickness 1.5 km. The cloud has a liquid water content of 0.5 g m^{-3}.

Determine the size of the raindrop emerging from the cloud base. You can assume that there is negligible updraught in the cloud; that the fall velocity of the cloud droplet is much less than that of the raindrop and that $E_{collection}$ is equal to 1.

[3 marks]

Q.5 Write notes on <u>two</u> of the following:

(a) Electrification in the atmosphere. [5 marks]

(b) The formation and evolution of oxygen in the Earth's atmosphere. [5 marks]

(c) Carbon dioxide and the carbon cycle, in the context of the greenhouse effect.

[5 marks]

Q.6 Give a detailed account of stratospheric ozone, including in particular its formation and destruction. Explain the scientific basis of the processes involved, with regard to both natural and anthropogenic causes. Discuss the important role of the meteorology of the stratosphere. Comment on the important differences between the situations in the Arctic and the Antarctic regions. [10 marks]

Q.7 Give an account of the main features of the ionosphere and explain how they may be investigated. With the aid of a simple diagram, show the typical variation of free electron concentration with altitude, by day and by night. [5 marks]

The following expression gives the plasma frequency appropriate for a particular level in the ionosphere:

$$fp^2 = Ne^2 / (4\pi\varepsilon_o m_e)$$

Explain what the various parameters and constants represent and show that the expression can be written in the approximate form:

$$f_p \approx 9N^{1/2}\ \mathrm{Hz}$$

[2 marks]

Pulses of frequency 8.0 MHz are transmitted vertically upwards by an ionosonde and are received back at the same location after a time interval of 2.0 ms. Deduce as much information as you can with regard to the vertical profile of ionisation at that place and time. [3 marks]

Q.8 Show that, for an observer on the Earth, air moving horizontally with a speed v at latitude ϕ in the Northern Hemisphere, is subject to a transverse acceleration $a = fv$ to its right. The Coriolis parameter $f = 2\Omega \mathrm{Sin}\phi$, where Ω is the angular velocity of rotation of the Earth around its axis. [3 marks]

Derive the geostropic wind equation,

$$V_g = -\ (1/pf)\ (\Delta p/\Delta H)$$

Specify assumptions made in the derivation and explain the parameters involved in the equation. [4 marks]

What perpendicular distance separates isobars of 992 hPa and 996 hPa, at a mean latitude of 60° on a surface chart, when the geostropic wind speed is 20 m s^{-1} ? The density of the air is 1.29 kg m^{-3}. [3 marks]

Numerical values of some physical quantities

Radius of the Earth	=	6,371 km
Stefan's constant, σ	=	5.67×10^{-8} W m^{-2} K^{-4}
Earth's angular velocity of rotation, Ω	=	7.292×10^{-5} radian s^{-1}
Magnitude of the electronic charge, e	=	1.60×10^{-19} C
Electron mass, m_e	=	9.11×10^{-31} kg
Permittivity of free space, ε_o	=	8.85×10^{-12} F m^{-1}
Velocity of light in air, c	=	3.0×10^{8} m s^{-1}