RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

B.Sc. (General) Degree in Applied Sciences
Third Year - Semester I Examination – November/December 2016

PHY 3301 – ATMOSPHERIC PHYSICS

Time: Three (3) hours

Instructions:

1. Answer **all** the questions
2. Only the calculators provided by the university are allowed to be used.

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \text{ms}^{-1}$
electron charge	$e = 1.60 \times 10^{-19}\ \text{C}$
the Plank constant	$h = 6.63 \times 10^{-34}\ \text{J s}$
mass of electron	$\text{m}_e = 9.11 \times 10^{-31}\ \text{kg}$
mass of proton	$\text{m}_p = 1.67 \times 10^{-27}\ \text{kg}$
acceleration of free fall on the Earth's surface	$g = 9.81\ \text{m s}^{-1}$
electron volt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$
Rydberg constant	$R_H = 1.097 \times 10^{7}\ \text{m}^{-1}$
Atomic mass unit	$1\ \text{u} = 931.6\ \text{MeV}$
Angstrom	$1\text{Å} = 1 \times 10^{-10}\ \text{m}$

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1. (a) What are the distingiushing characteristics of the troposphere, stratosphere, mesosphere and thermosphere? (8 marks)

   (b) What is outgasing and why was it important? (3 marks)

(c) Why were anaerobic bacteria important to the evolution of the atmosphere? (3 marks)

(d) "The greenhouse effect is responsible for keeping the Earth a habitable place. However, this phenomenon has been enhanced by human activity making the Earth sub-optimal for many species". Briefly discuss this statement. (6 marks)

2. (a) Explain how in winter heat is transferred by,

(i) Conduction (2 marks)

(ii) Convection (2 marks)

(iii) Radiation (2 marks)

(b) Compare and contrast Rayleigh and Mie scattering (4 marks)

(c) How would an Earth's increase in temperature influence the amount of radiation emitted by Earth's surface? (3 marks)

(d) What is the most important factor responsible for seasons on Earth? Why? (2 marks)

(e) If Earth had no atmosphere, its long wave radiation emission would be lost quickly to space, making the planet approximately 33 K cooler. Calculate the rate of radiation emitted (E), and the wavelength of maximum radiation emission λ_{max} for Earth at 255 K. ($\sigma = 5.67\times10^{-8}\mathrm{W/m^2K^4}$, Wien's constant $C = 2898\ \mu\mathrm{mK}$). (5 marks)

3. (a) Define *Ideal Gas Law* (3 marks)

(b) A sample of 100 g of dry air has an initial temperature of 270 K and pressure 900 mb. During an isobaric process heat is added and the volume expands by 20% of its initial volume ($R_{dry\ air}$ = 287.058 J kg^{-1} K^{-1}, 1mb = 100 Pa). Estimate:

(i) The final temperature of the air (4 marks)

(ii) The amount of heat added (3 marks)

(iii) The work done against the environment (3 marks)

(c) One mole of dry air (molar mass of dry air = 28.97 g/mol) has an initial state T = 273 K and p = 1 atm (1 atm = 101325 Pa). It undergoes a process in

which its volume becomes four times its initial volume at 400 mb. If air is considered an ideal gas and if the process obeys the law $pV^{\eta} = \text{constant}$, estimate:

(i) The value of η, (4 marks)

(ii) The final temperature, (3 marks)

4. (a) Explain the concept of Hydrostatic equilibrium. (3 marks)

(b) Use the hydrostatic equation and show that the **mass of a vertical column of air of unit cross-section**, extending from the ground to a great height, is p_0/g, where p_0 is the surface pressure. (4 marks)

(c) The geopotential height is the height of a given pressure level. Show that in an atmosphere with **uniform lapse rate** (i.e. $\frac{dT}{dZ} = \Gamma = \text{constant}$) the geopotential height at a pressure p is given by,

$$z = \frac{T_0}{\Gamma}\left[1 - \left(\frac{p_0}{p}\right)^{\frac{-R_d T}{g}}\right]$$

where, T_0 is the temperature at z = 0. (7 marks)

(d) In an **isothermal** atmosphere, obtain an expression for the **geopotential height** as a function of pressure, and show that this is consistent with the above equation in an appropriate limit. (4 marks)

5. (a) Define relative humidity (3 marks)

(b) What are condensation nuclei? Are they typically made of the same materials? (3 marks)

(c) What process that leads to saturated air causes the 'fog' that forms in the bathroom when you take a shower. Explain. (4 marks)

(d) How does droplet size affect rates of evaporation and condensation? (3 marks)

(e) The data in Table 5.1 below represent the dew-point temperature and expected minimum temperature near the ground for various clear winter mornings in a southeastern city in USA. Assume that the dew point remains constant throughout the night. Answer the following questions using both table 5.1 and 5.2.

I. On which morning would there be the greatest likelihood of observing visible ***frost***? Explain why. (4 marks)

II. On which morning would ***frozen dew*** most likely form? Explain why. (3 marks)

Table 5.1

	Morning 1	Morning 2	Morning 3	Morning 4	Morning 5
Dew-point temperature	2°C (35°F)	−7°C (20°F)	1°C (34°F)	−4°C (25°F)	3°C (38°F)
Expected min temperature	4°C (40°F)	−3°C (27°F)	0°C (32°F)	−4.5°C (24°F)	2°C (35°F)

Table 5.2

Air temperature		Saturation vapor pressure	Air temperature		Saturation vapor pressure
(°C)	(°F)	(MB)	(°C)	(°F)	(MB)
-18	(0)	1.5	18	(65)	21.0
-15	(5)	1.9	21	(70)	25.0
-12	(10)	2.4	24	(75)	29.6
-9	(15)	3.0	27	(80)	35.0
-7	(20)	3.7	29	(85)	41.0
-4	(25)	4.6	32	(90)	48.1
-1	(30)	5.6	35	(95)	56.2
2	(35)	6.9	38	(100)	65.6
4	(40)	8.4	41	(105)	76.2
7	(45)	10.2	43	(110)	87.8
10	(50)	12.3	46	(115)	101.4
13	(55)	14.8	49	(120)	116.8
16	(60)	17.7	52	(125)	134.2