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RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

B.Sc. (General) Degree
Third Year – Semester I Examination – October / November 2015

PHY 3301 – ATMOSPHERIC PHYSICS

Answer **all** questions

Time allowed: **3** hours

Gravitational acceleration	$g = 9.8\ ms^{-1}$
Pressure at sea level	1 atm = 1013 hPa
Universal gas constant	$R = 287\ JK^{-1}kg^{-1}$

1. (a) The atmosphere is divided vertically into four layers on the basis of temperature. Briefly describe the four layers. [8 marks]

   (b) On a spring day a middle-latitude city (about 40°N latitude) has a surface (sea level) temperature of 10°C. If vertical soundings reveal a nearly constant environmental lapse rate of 6.5°C per kilometer and a temperature at the tropopause of –55°C, what is the height of the tropopause? [3 marks]

   (c) On the same spring day a station near the equator has a surface temperature of 25°C, 15°C higher than the middle-latitude city mentioned in part a. Vertical soundings reveal an environmental lapse rate of 6.5°C per kilometer and indicate that the tropopause is encountered at 16 kilometers. What is the air temperature at the tropopause? [3 marks]

   (d) If you were suddenly placed at an altitude of 100 km (62 mi) above the earth, would you expect your stomach to expand or contract? Explain. [4 marks]

2. (a) Explain why the atmosphere is heated chiefly by radiation from Earth's surface rather than by direct solar radiation. [3 marks]

   (b) Which gases are the primary heat absorbers in the lower atmosphere? Explain. [5 marks]

(c) How does Earth's atmosphere act as a greenhouse? [4 marks]

(d) What is the "villain" in the global warming problem? Explain. [3 marks]

3. Consider a hydrostatic atmosphere with constant lapse rate.

(a) Derive an expression for the **variation of height with pressure, $z(p)$,** in terms of the surface pressure P_0, surface temperature T_0, and lapse rate Γ. This equation forms the basis for the calibration of aircraft pressure altimeters, where T_0 = 288K, $P_0 = 1013.25$ hPa, and $\Gamma = 6.5°\text{C km}^{-1}$ (U.S. Standard Atmosphere). [4 marks]

(b) An aircraft flying at pressure of 850 mb is preparing to land. Calculate the height above the surface (assume the surface is at sea level) that the aircraft is flying, using the altimeter correction for the standard atmosphere. [4 marks]

(c) On February 3, 1989, sea-level pressure reached a North American record of 1078 hPa. Surface temperature reached a minimum value of 217 K. The vertical temperature profile in the lower atmosphere was nearly isothermal. For an aircraft flying at a pressure of 850 mb above a surface that is at sea level, estimate the error in the **altimeter** reading that would be made under these conditions. (Note: The U.S. Federal Aviation Administration banned night and instrument flights in Fairbanks, AK, because altimeters could not be accurately calibrated to give altitude readings.) ($\Gamma = 6.5°\text{K km}^{-1}$, $R = 287\ \text{JK}^{-1}\text{kg}^{-1}$, 1hPa = 100 Pa = 1 mb) [4 marks]

4. (a) Prove that for any system,

$$\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial p}{\partial T}\right)_V - p$$

where, U = internal energy, V = volume of the system, p = pressure exerted by the surroundings to the system and T = temperature of the system.

(Hint: consider first law of Thermodynamics, $dS = \delta Q/T$ where S is the entropy of the system, and the fact that dS is an exact differential) [4 marks]

(b) Using the above equation, show that an ideal gas U is only a function of temperature and does not depend on V (Joule's law). [3 marks]

(c) A substance obeys the equation of state $pV^{1.2} = 10^9 T^{1.1}$. A measurement of its internal capacity inside a container having a constant volume of 100 liters shows that under these conditions the thermal capacity, $(\partial U/\partial V)_T/p$ is constant and equal to 0.1 cal K^{-1}. Express the energy and the entropy of the system as a

function of T and V. (Hint: Start from the equation in part (a). Is the substance an ideal gas?) [4 marks]

5. (a) What is a stable atmosphere? [3 marks]

(b) Describe the steps in the formation of precipitation according to the Bergeron process. Be sure to include the importance of supercooled cloud droplets, the role of freezing nuclei and the difference in saturation vapor pressure between liquid water and ice. [4 marks]

(c) How does the collision-coalescence process differ from the Bergeron process? [3 marks]

(d) If snow is falling from a cloud, which process produced it? Explain. [4 marks]