The Open University of Sri Lanka
Faculty of Natural Sciences
B.Sc/ B. Ed Degree Programme

Department	: Physics
Level	: 5
Name of the Examination	: Final Examination
Course Code and Title	**: PHU5302 - Atmospheric Physics**
Academic Year	: 2023/2024
Date	: 12th October 2023
Time	: 9.30 a.m. -11.30 a.m.
Duration	: Two (2) hours

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **6** questions in **4** pages.
3. Answer any **4** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. Draw fully labelled diagrams where necessary
5. Relevant log tables are provided where necessary.
6. Having any unauthorized documents/ mobile phones in your possession is a punishable offense.
7. Use blue or black ink to answer the questions.
8. Circle the number of the questions you answered in the front cover of your answer script.
9. Clearly state your index number in your answer script

$\varepsilon = 0.622$ $g_0 = 9.8\, m/s^2$

R_d=287 *J /kg K*

R_v=461 *J /kg K*

R* =0.08205 *l atm /mol K* =8.314 *J /mol K*

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

Air density =1.225 $kg\ /\ m^3$

Molecular weight of CO_2 =44.009 *g/mol*

L_v =2.5x10^6 *J / kg K*

Answer 4 questions only.

01.

(a) Earth's atmospheric layers are defined based on temperature with height.

i. What causes the temperature to decrease with height through the troposphere and decrease with height through the stratosphere?

ii. Why is the mesosphere colder than the thermosphere?

(4 marks)

(b) Wind can be quite variable. There are few basic ways that the air can be moved in the Atmospheric boundary layer (ABL) and the total wind speed is the superposition of all such flow types.

i. Classify the air flow in the Atmospheric boundary layer (ABL) with the aid of a diagram?

ii. Briefly explain each air flow type in the Boundary layer stating the major characteristics.

(9 marks)

(c) In regions where the pressure changes with distance, there is a pressure gradient force from high to low pressure.

i. The effects of the pressure gradients are usually expressed in terms of pressure gradient force per unit mass. Write down the equations for horizontal components ($\mathbf{a}_x$, $\mathbf{a}_y$) of pressure gradient force. State all symbols used.

ii. Negambo is about 37.5 km north of Colombo in the Western Province of Sri Lanka. The sea level pressure values at Negambo and Colombo are 1013 hPa and 1012 hPa respectively. What is the value of the northward pressure-gradient force per unit mass?

(7 marks)

(d) What is the geostrophic flow in the atmosphere? Derive the equations for horizontal components (U_g,, V_g) of the wind that defines the geostrophic balance. State all assumptions made and identify all symbols used.

(5 marks)

02.

(a) What is an ideal gas? Under what conditions does a real gas behave ideally?

(4 marks)

(b) An empty sealed 3.5-liter container is filled with 11.2 g of solid CO_2 at a temperature of 27 °C. When all the solid CO_2 becomes gas and behaves as an ideal gas, what will be the pressure inside the container?

(3 marks)

(c) A very common way to describe the atmosphere of a planet is by its 'scale height'.

i. If the density of air on Earth decreases exponentially with height from a value of 1.225 kg m^{-3} at sea level, calculate the scale height that is consist with the observed sea level pressure of 1013.25 hPa?

ii. What is the physical interpretation of the scale height you have calculated?

(10 marks)

(d) Enthalpy (h) is an energy quantity that accounts not only for internal energy but also the energy associated with working. Derive the first law of thermodynamics in terms of enthalpy. Show that $h = CpT$, where Cp is the specific heat at constant pressure.

(8 marks)

03.

(a) An air parcel at 1013 hPa pressure and at 25 °C contains 6 g of water vapor. The volume of the air parcel is 1.2 m^3. If T_0 =273 K and e_0=611 Pa, estimate the values below.

i. Absolute humidity
ii. Vapor pressure
iii. Saturation vapor pressure
iv. Relative humidity?

(10 marks)

(b) Briefly explain how wet bulb temperature is measured. What is the difference between dry bulb and wet bulb temperature during the unsaturated and saturated conditions in the atmosphere?

(5 marks)

(c) Atmospheric stability can be determined using lapse rates.

i. What is meant by the moist adiabatic lapse rate? Why is it less than the dry adiabatic lapse rate?

(3 marks)

ii. The temperature at the ground at an observatory in the south pole was -80°C while the temperature at the top of a 35 m tower was −40°C. Estimate the lapse rate within the lowest 40 m.

(2 marks)

(d) Show that the pressure variation of isothermal atmosphere is $P = P_0 e^{-\frac{z}{H}}$.

(5 marks)

04.

(a) Define the solar constant. If the value of solar constant is 1360 W/m^2, determine the temperature of the Sun's surface. The radius of the Sun is 7×10^8 m and the average distance between the earth and the Sun is1.5×10^{11} m.

(7 marks)

(b) The radiant power of a small light source is 200 mW.

i. If it emits light with spherical symmetry determine the radiant intensity of the light source?

ii. The light source creates a circular spot with 8 cm diameter on a wall. What is the irradiance on the wall?

(6 marks)

(c) Describe the physical cause of following atmospheric phenomena.

i. Mirage

ii. Primary rainbow

(8 marks)

(d) Why do mountains look blue at a distance?

(4 marks)

05.

(a) Explain the cloud formation process?

(5 marks)

(b) What is meant by terminal velocity? State the equation for terminal velocity (VT) defining the terms used.

(4 marks)

(c) What is the difference between accretion and aggregation in ice crystal growth?

(4 marks)

(d)

i. What are the main features of MCCs and supercell thunderstorms?

ii. What is the role of thunderstorms in global electric circuit?

iii. Why does St Elmo's fire only occur during thunderstorms?

(12 marks)

06.

(a) What is meant by ITCZ? Briefly discuss its features, shifting nature of the position throughout the year and importance.

(7 marks)

(b) Derive the thermodynamic energy equation using the first law of thermodynamics. State the variables and symbols used.

(7 marks)

(c) What is a geostationary satellite and what is it used for?

(5 marks)

(d) The Earth's climate has changed over the centuries and millennia due to a number of different factors? Briefly explain 3 factors.

(6 marks)

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