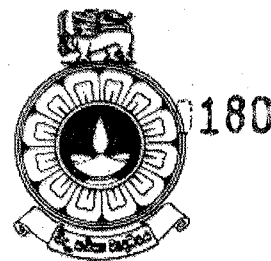


The Open University of Sri Lanka
Faculty of Natural Sciences
B.Sc/ B. Ed Degree Programme



Department	: Physics
Level	: 5
Name of the Examination	: Final Examination
Course Code and Title	: PHU5302 - Atmospheric Physics
Academic Year	: 2025/2026
Date	: 7 th January 2026
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 **5** 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

Constants:

$$\varepsilon = 0.622$$

$$R_d = 287 \text{ J/kg K}$$

$$R_v = 461 \text{ J/kg K}$$

$$g_0 = 9.8 \text{ m/s}^2$$

$$C_p = 1004 \text{ J/kg K}$$

$$C_v = 718 \text{ J/kg K}$$

$$\Gamma_d = 9.8 \text{ }^\circ\text{C/km}$$

$$\Gamma_m = 6.0 \text{ }^\circ\text{C/km}$$

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

Answer 4 questions only.

01.

- (a) Earth is surrounded by an atmosphere made up of several different gases. Describe the difference between permanent gases and variable gases in the atmosphere.

(4 marks)

- (b) Describe how energetic particles from the Sun affect both the ionosphere and the exosphere.

(4 marks)

- (c) Briefly describe the three main components of air flow in the atmospheric boundary layer (ABL) and explain the key features and their importance in atmospheric processes.

(9 marks)

- (d) A radiosonde launched at Station A shows the 500 hPa height is 50 m higher than at Station B, which lies 250 km to the east. In the same region at the surface (40°N), the observed wind speed is $15 \text{ m}\cdot\text{s}^{-1}$ blowing from the west. Assume f as $9.4 \times 10^{-5} \text{ s}^{-1}$.

- Calculate the geostrophic wind speed at 500 hPa using the given east–west height difference. Determine the direction of the geostrophic wind relative to the height gradient.
- Using the $15 \text{ m}\cdot\text{s}^{-1}$ surface wind, calculate the Coriolis force per unit mass acting on an air parcel.
- Explain why surface winds are typically weaker than the geostrophic wind found above the boundary layer.

(8 marks)

02.

- (a) A research drone operates in the mid-troposphere where the air pressure is 600 hPa, the air temperature is -10°C , and the water vapor pressure is 1.2 hPa. The drone uses a sealed airbag system with a volume of 4.0 m^3 at this altitude.

- Calculate the virtual temperature (T_v) of the ambient air at this altitude.
- Using your virtual temperature, determine the density (ρ) of the ambient air.
- Calculate the mass of the air within the airbag.
- If the drone and instruments have a total mass of 3.8 kg, calculate the buoyant force acting on the drone at this altitude and determine whether the drone will rise or sink.

(8 marks)

- (b) Define geopotential and geopotential height.

(4 marks)

(c)

- Derive the first law of thermodynamics in terms of specific heat capacity at constant volume and show that the change in internal energy is $du = m C_v dT$ for a fixed mass m .

- ii. A 1.0 kg parcel of dry air in the lower troposphere is compressed slowly by the surrounding air. During the compression the surroundings do 150 J of work on the parcel, and the parcel loses 200 J of heat to the surroundings. Assume that the air as an ideal gas with constant specific heats and compute the change in internal energy (ΔU), temperature change (ΔT) and change in enthalpy (ΔH) of the parcel.

(8 marks)

- (d) Air parcels rising in the troposphere often cool nearly adiabatically. During a dry adiabatic ascent, the temperature of the parcel decreases, yet its entropy remains constant. Explain why the entropy does not change even though the parcel becomes colder.

(5 marks)

03.

- (a) The ambient air temperature and dew point temperature at a weather station are 32°C and 22°C, respectively. Measurements showed that saturation vapour pressure at ambient temperature is 47.4 hPa and at dew point temperature it is 26.4 hPa.

- Define the dew point temperature.
- Determine the actual vapour pressure of the air.
- Calculate the relative humidity of the air.
- If the air cools at constant pressure with no change in water vapour content, determine the temperature at which condensation will begin and briefly explain your answer.

(8 marks)

- (b) An air parcel at the earth surface (ground level) has a temperature of 30°C. A radiosonde observation provides the following environmental air temperatures at different heights. Assume that the parcel remains in pressure equilibrium with the environment. The parcel cools at the dry adiabatic lapse rate from the surface to 1500 m, and at the moist adiabatic lapse rate above 1500 m.

Height	Environmental Temperature
Surface (0 m)	30°C
2000 m	10°C
4000 m	-6°C

- Calculate the temperature of the parcel at 1500 m, 2000 m, and 4000 m.
- Compare the parcel temperature with the environmental temperature at 2000 m and 4000 m and determine the parcel's buoyancy at each level. Discuss the atmospheric stability below and above 1500 m.
- Briefly describe the expected vertical motion and cloud development under these conditions.

(8 marks)

- (c) Assume a hypothetical homogeneous atmosphere of finite height H , in which the air behaves as an ideal gas.

Starting with the hydrostatic equation derive:

- An expression for the maximum height H of the atmosphere in terms of surface temperature T_0 , the specific gas constant R , and the gravitational acceleration g .
- The corresponding temperature variation with height and hence show that the temperature lapse rate in a homogeneous atmosphere is $\frac{dT}{dz} = -\frac{g}{R}$.

(5 marks)

- (d) State 4 main characteristics of a Stüve diagram.

(4 marks)

04.

- (a) Why is the atmosphere considered transparent to visible radiation but absorbing in the infrared?

(4 marks)

- (b) Planet earth behaves as a blackbody in radiative equilibrium. If the solar constant is 1367 W/m^2 .

- i. Calculate Earth's effective temperature assuming an albedo of 0.30.
- ii. Briefly explain how changes in albedo influence Earth's climate.

(6 marks)

(c)

- i. Distinguish between Rayleigh scattering and Mie scattering in terms of particle size.
- ii. Explain why the sky appears blue during the daytime.
- iii. Explain why the Sun appears red or orange during sunrise and sunset.

(8 marks)

(d)

- i. Describe, with the aid of a diagram, the sequence of optical processes that occur when sunlight enters a spherical raindrop and lead to the formation of a primary rainbow.
- ii. Explain why a secondary rainbow appears at a larger angle and has reversed colour order compared to the primary rainbow.

(7marks)

05.

(a)

- i. Briefly explain what is meant by nucleation in clouds.
- ii. Explain the role of cloud condensation nuclei in the formation of liquid clouds

(4 marks)

- (b) A spherical cloud droplet of radius $20 \mu\text{m}$ is falling through, still air in a cloud.

The density of liquid water (ρ_L) is 1000 kg m^{-3} , and the dynamic viscosity of air (μ) is $1.8 \times 10^{-5} \text{ kg m}^{-1} \text{ s}^{-1}$. Assuming that the droplet is small enough for Stokes' law to apply and neglecting the air density;

- i. Write down the expression for the terminal velocity of a small spherical particle falling under Stokes' law.
- ii. Calculate the terminal velocity of the cloud droplet.

(5 marks)

- (c) Explain how aggregation differs from riming in precipitation formation.

(4 marks)

- (d) Explain the energy source of a tropical cyclone and how latent heat release drives strong winds in the cyclone.

(4 marks)

- (e) Describe the sequence of processes that lead to cloud-to-ground lightning.

(8 marks)

06.

(a) Briefly describe the pressure belts in the three-cell model of the global wind system.
(8 marks)

(b) Derive the thermodynamic energy equation starting from the first law of thermodynamics, including the diabatic heating rate J . Clearly state/identify the symbols used.
(7 marks)

(c) Briefly explain the working principle of Dobson spectrometer.
(4 marks)

(d) Briefly explain following climate feedback mechanisms

- i. Land carbon cycle
- ii. Increase in global temperature.

(6 marks)

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