2022

M.Sc.

Fourth Semester

DISCIPLINE SPECIFIC ELECTIVE – 03

PHYSICS

Course Code: MPHD 4.11(A)

(Atmospheric Physics)

Total Mark: 70 *Pass Mark: 28*

Time: 3 hours

Answer five questions, taking one from each unit.

UNIT–I

1. (a) Define lapse rates below and above lifted condensation level. Write the criteria for the conditional instability of the atmosphere. 4

   (b) Define convective available potential energy (CAPE) and find its relationship with vertical velocity. 3

   (c) An air parcel is lifted from the ground. At 5 km. height, the environmental temperature (T_E), parcel temperature (T_p) and the dew point temperature (T_D) are –11°C, –9°C and –9°C respectively. Explain the stability and saturation state of the parcel. 2

   (d) Consider a thermodynamic system of water and ice at equilibrium with water vapor. Derive the equations for saturated vapor pressure over ice and liquid water. 5

2. (a) Consider a state of gas where condensation and evaporation occurs simultaneously. If at equilibrium, the saturation vapor pressure is e_s and temperature is T, derive the relation between the change in e_s with change in T. 4

   (b) If water droplets are in equilibrium with surrounding at a temperature of 2°C, calculate vapor pressure and mixing ratio. 4

   (c) Define virtual temperature and derive the expression for it. Calculate virtual temperature of moist air at a temperature of 30°C. [Given, a mixture of 20 g of water in 1 kg of dry air.] 6

UNIT–II

3. (a) Consider a water droplet of radius r with surface tension σ density ρ_L and temperature T. Find the expression for the critical radius of the droplet. 3

(b) Show that for heterogeneous nucleation, the ratio of the saturated vapor pressure over a solution and over the flat surface can be written as $\frac{e_s'(r)}{e_s(\infty)} = 1 + \frac{a}{r} - \frac{b}{r^2}$, where symbols have their usual meanings. Explain the corresponding Kohler curve and critical supersaturation. 6

(c) Assume water droplets are in equilibrium with surrounding vapor at a temperature 2°C. Find the ratio between ambient vapor pressure to saturation vapor pressure required to form a water droplet of radius 0.008 μm. The surface tension of water is 0.076 Jm^{-2} 5

4. (a) Show that the diffusional growth of a droplet of mass m is given by

$$\frac{dm}{dt} = (r\pi r D\rho_{vr})\frac{\rho_v - \rho_{vr}}{\rho_{vr}}$$, where symbol have their usual meanings.

5

(b) What are the types of aerosols? Explain briefly the role of aerosol on cloud formation. 3

(c) Explain different electrification mechanisms in thundercloud and thundercloud currents. Find the dipole moment of a thundercloud having positive dipole charge structure at a distance. What is reversal distance? 6

UNIT–III

5. (a) Name the fundamental governing forces for the atmospheric motions. Derive the expressions for pressure gradient force and viscous force in the atmosphere. 7

(b) Define centripetal acceleration and derive the expression for it.

Show that Coriolis force per unit mass is given by $F_{cor} = -2\Omega \times V$.

7

6. (a) Show that total differentiation for temperature advection can be expressed as $\frac{DT}{Dt} = \frac{\partial T}{\partial t} - U.\nabla T$, where $U = u\hat{i} + v\hat{j} + w\hat{k}$ is the velocity vector and T is the temperature. 6

(b) Derive the vectorial form of momentum equations for atmospheric motions. Write the approximate prognostic momentum equations and calculate Rossby number. 8

UNIT–IV

7. (a) Describe Atmospheric turbulence. What is Boussinesq approximation? Write the planetary boundary layer equations based on Boussinesq approximation. 5

(b) Explain Reynolds averaging for a turbulent fluid. Deduce the boundary layer equations after Reynolds averaging and explain the covariance terms. 6

(c) Write the expression for turbulent kinetic energy and explain each term. 3

8. (a) What is meant by well-mixed boundary layer. Write the bulk aerodynamic formula for well-mixed boundary layer and explain characteristics of potential temperature and mean zonal wind profile. 6

(b) Write a short note on the following: 4×2=8

(i) The mixing length hypothesis

(ii) The Ekman layer

UNIT–V

9. (a) Write the fundamental equations for numerical weather prediction (NWP). Using the advection equation, explain the finite difference method for NWP. Write the conditions for finite difference method and computational stability? 6

(b) What is grid staggering? Describe Arakawa C grid staggering mechanism. Write the basic principles of parameterization. Explain briefly different types of physical parametrization used in NWP. 8

10. (a) Derive the radiative temperature for global radiation balance (T_{rad}). If a fraction of 30% of incoming solar radiation is reflected back by the Earth, what is the value of T_{rad}? Explain why this value is much lower/higher than the mean temperature of the Earth's surface. [Use, $\sigma = 5.67 \times 10^{-8}$ $Wm^{-2}K^{-4}$, radius of Earth (R) = 6370 km, the solar flux at the Earth's orbit is $F_s = 1370$ Wm^{-2}] 4

(b) "Energy deposition is not uniform with latitude." Explain with proper equations. 4

(c) Write a short notes on the following: 6

(i) Three-cell model

(ii) Inter tropical convergence zone (ITCZ)

(ii) Maddan-Julian oscillations
