2023

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) Discuss the composition and structure of the atmosphere with a figure describing the vertical structure of the atmosphere. 7
   (b) A gas mixture of 300 L at 273 K and total pressure of 0.75 atm contains 6.7 mol of hydrogen gas and 3.3 mol of oxygen gas. What is the partial pressure of hydrogen gas? 3
   (c) Calculate the virtual temperature correction for moist air at 30°C that has a mixing ratio of 20 g kg^{-1}. 4

2. (a) Show that adiabatic process is an isentropic process. 7
   (b) Derive the Poisson's equation for pressure and temperature. Show that potential temperature is a conservative property. 5+2=7

UNIT–II

3. (a) Explain condensation level. What are the factors that lead to air rising and cooling? 2+4=6
   (b) Discuss the growth of cloud droplet by condensation along with the relationship of relative humidity, super saturation and droplet radius for curved surface undergoing curvature effect. 6
   (c) What are super cooled liquids? 2

4. (a) Show that the solution effect dominates when the radius of droplet is small for a Kohler curve. 5
   (b) What are thunderstorms? How is it formed? 1+4=5

(c) Determine the fraction of the mass of a supercooled droplet that is frozen in the initial stage of freezing if the original temperature of the droplet is –20°C. What are the percentage increases in the volume of the droplet due to the first and to the second stages of freezing? (Latent heat of melting = 3.3×10^5 Jkg^{-1}; specific heat of liquid water = 4218 $J K^{-1} kg^{-1}$; specific heat of ice = 2106 $J K^{-1}$; density of ice = 0.917×10^3 kgm^{-3}) 4

UNIT–III

5. (a) What are body and surface force? 3
   (b) Derive the equation of continuity in Eulerian form. 7
   (c) Write a short note on Rossby number. 4

6. (a) Derive the equation of motion in tangential local coordinates. 6
   (b) Derive an expression for equation of motion of synoptic and large motion in spherical coordinates. 5
   (c) During winter in the troposphere at 30° latitude, the zonally averaged temperature gradient is found to be 0.75 K per degree of latitude and the zonally averaged component of the geostrophic wind at the Earth's surface is close to zero. Estimate the mean zonal wind at the jet stream level of 250 hPa. 3

UNIT–IV

7. (a) What is barotropic instability? Show that the absolute vorticity must be a constant somewhere in the flow for barotropic instability. 3+4=7
   (b) Derive the governing equations of the planetary boundary layer using Boussinesq approximation. 7

8. (a) What is perturbation theory? Derive the condition that the perturbation field is very small compared to the static field in linear perturbation theory. 2+4 =6
   (b) Write a short note on the following: 4×2 =8
      (i) Kelvin-Helmholtz instability
      (ii) The planetary boundary layer

UNIT–V

9. (a) Show that the potential vorticity flux is directly proportional to the divergence of the Eliassen-Palm flux vector. 6

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

   (i) Hadley circulation

   (ii) Ferrel cells

10. (a) Calculate the rate of change of the absolute angular momentum of unit mass at a certain latitude with an assumption that the horizontal eddy stress is negligible compared to vertical eddy stress. 7

    (b) What are climate models? Write the basic equations in a climate model. 2+3=5

    (c) Explain briefly data assimilation in numerical weather prediction model. 2