2024

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) Determine the variation of the equilibrium vapor pressure with respect to temperature for a heterogenous system. 7
   (b) What is a tephigram? Can the potential temperature remain constant in a dry adiabatic process? 1+6=7

2. (a) Evaluate the static stability of a parcel of air by the parcel method. What are the conditions for a dry, saturated and unsaturated air parcel to be stable, unstable and neutral condition? Obtain the conditional instability of a parcel of air. 3+6+2=11
   (b) The globally averaged surface pressure is 985 hPa. Estimate the mass of the atmosphere. 3

UNIT–II

3. (a) Prove the Raoult's law. 6
   (b) Depict the growth of a cloud droplets by condensation with the help of a graph relating relative humidity and super saturation with droplet radius. 6
   (c) What is riming and accretion? 2

4. (a) How are cloud droplets formed? 5

(b) Explain the Bergeron-Findeisen process. 5

(c) The rate of charge generation in a thunderstorm is 1 $Ckm^{-3}min^{-1}$. Determine the electric charge that would have to be separated for each collision of an ice crystal with a graupel particle (rimer) to explain the rate of charge generation. The concentration of ice crystals is $10^5 m^3$, their fall speed is negligible compared to that of the rimer, the ice crystals are uncharged prior to colliding with the rimer, their collision efficiency with the rimer is unity, and all of the ice crystals rebound from the rimer. The rimers are spheres of radius 2 mm, the density of a rimer is 500 kg m^{-3}, and the precipitation rate due to the rimers is 5 cm per hour of water equivalent. 4

UNIT–III

5. (a) Determine the gravitational force per unit mass exerted on the atmosphere. 5

(b) Evaluate the equations of motion in a coordinate system rotating with the earth by taking into account the Coriolis force due to the rotation of the earth. 9

6. (a) A parcel has a density of 0.7 kgm^{-3}embedded in a field of pressure with a gradient 10 hPa over 1000 km. Determine the acceleration of the parcel (ignoring the Coriolis force) and its increase in speed from rest in passing over 1000 km. 4

(b) A parcel of air of 1 kg moves horizontally along an isobaric surface and is heated by radiation by 4 Wkg^{-1}. What is the rate of change of temperature of the parcel? If the parcel is moving eastward along the horizontal isobaric surface at a velocity of $3ms^{-1}$ and that the eastward component of the gradient of temperature is given by 1.5 Kkm^{-1}. Calculate the local (fixed position) rate of change of temperature. 3+3=6

(c) At the 300-hPa (around10 km) level along 40° N during winter, the zonally averaged zonal wind [u] is eastward at 20 ms^{-1} and the zonally averaged meridional wind component [v] is southward at 30 cms^{-1}. Estimate the vorticity and divergence averaged over the polar cap region poleward of 40°N.

UNIT–IV

7. (a) Evaluate the mixing length theory with a schematic figure. 7

   (b) Derive an expression for the Ekman layer depth and show from the relevant hodograph that the velocity vector traces out a spiral shape with height. 4+3=7

8. (a) A turbulent flow is described by the velocity profile,

$$u = \frac{u_t}{0.12} \ln\left[\frac{z}{z_0}\right]$$

   such that u is the velocity at the height (z) of 9 km with frictional velocity (u_t) of 0.36 m/s and roughness length (z_0). Determine the mixing length if an air parcel have a vertical velocity of 3 m/s to move it upward by a distance of 0.09 mm. 6

   (b) Compute the effective depth of the Ekman layer if the turbulent transfer coefficient for momentum is found to be around 10 $m^2\ s^{-1}$ with a Coriolis parameter of $10^{-4}\ s^{-1}$. 4

   (c) Write a short note on gravity waves. 4

UNIT–V

9. (a) Evaluate how the Eulerian mean equations can be obtained by taking its zonal average by considering its eddies and mean flow. Write two advantages of zonally averaged circulation. 7+2=9

   (b) Explain the walker circulation with appropriate diagram. 5

10. (a) Highlight the angular momentum budget with proper diagrams to obtain the rate of change of angular momentum with respect to time in terms of the zonal component of the vertical stress in isobaric coordinates. 6

(b) A flow is described by the velocity component, $u = -0.0003y$ (mm/s) and $v = 0.0005x$ (mm/s). Determine the vorticity of the flow at that point. 4

(c) Write a short note on data assimilation in numerical weather prediction. 4
