

**INDIA METEOROLOGICAL  
DEPARTMENT  
QUESTION BANK  
OF  
FORECASTERS TRAINING COURSE  
(FTC)**

**FINAL EXAMINATION**

**BASED ON 176-191 BATCHES**

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**PAPER-I: DYNAMIC METEOROLOGY**

**PART A**

**INDIA METEOROLOGICAL DEPARTMENT**  
**METEOROLOGICAL TRAINING INSTITUTE**  
**FORECASTER TRAINING COURSE**  
**PAPER I - DYNAMIC METEOROLOGY(PART-A)**

**Q.1 Fill in the blanks:**

1. \_\_\_\_\_ is the source of all energy.
2. \_\_\_\_\_ is the restoring force for gravity waves.
3. \_\_\_\_\_ of a westerly trough fall of pressure takes place.
4. \_\_\_\_\_ wave can transport momentum and energy in the vertical direction also.
5. \_\_\_\_\_ is the source of horizontal K.E.
6. \_\_\_\_\_ wave can transport momentum and energy in the Horizontal direction only.
7. \_\_\_\_\_ is the mechanism for conversion of I.E to K.E.
8. A circular low pressure system moves in \_\_\_\_\_ direction.
9. A stably stratified PBL is characterized by \_\_\_\_\_ turbulence.
10. Acceleration of circulation = -----
11. Ahead of an upper air westerly trough \_\_\_\_\_ of pressure occurs (fall/rise) 3. \_\_\_\_\_ enhances cyclonic circulation (convergence/divergence)
12. At left exit of sub tropical westerly jet core surface \_\_\_\_\_ forms.
13. Available potential energy in a \_\_\_\_\_ atmosphere is zero.
14. Baroclinic instability grows by extracting \_\_\_\_\_ from mean flow.
15. Baroclinic instability is a -----instability.
16. Belt of \_\_\_\_\_ is the source of horizontal kinetic energy.
17. Brant -Vaisala instability grows by extracting \_\_\_\_\_ energy from mean flow.
18. Circulation is a \_\_\_\_\_ scale measure of rotation (micro/macro)
19. Convective turbulence is maintained by -----term in TKE (Total Kinetic Energy) equation.
20. Convergence enhances \_\_\_\_\_ vorticity
21. Depth of Ekman layer is \_\_\_\_\_
22. Divergence \_\_\_\_\_ cyclonic circulation (enhances/reduces).
23. Divergence reduces \_\_\_\_\_ circulation.

24. Divergence results into \_\_\_\_\_ of cyclonic vorticity.
25. Divergence term in the pressure tendency equation is \_\_\_\_\_
26. Due to friction there is net \_\_\_\_\_ in zonal angular momentum in tropics.
27. Exchange of physical properties in PBL is taken place by ----- process.
28. Expression of circulation is \_\_\_\_\_ .
29. External gravity wave is a \_\_\_\_\_ wave.
30. Extra tropics lost zonal angular momentum due to \_\_\_\_\_.
31. For a dispersive wave, energy & momentum are carried with \_\_\_\_\_ speed (Same/Different).
32. For a non dispersive wave, group velocity and phase velocity are \_\_\_\_\_.
33. For Sea or Land breeze to occur, atmosphere must be -----.
34. For turbulent flow flux Richardson number should be \_\_\_\_\_.
35. Frictional force or Viscous force is dominant in the ----- of PBL.
36. Group velocity is the rate at which -----is transported by wave.
37. Group Velocity vector of a wave is -----
38. In a barotropic atmosphere Thermally \_\_\_\_\_ circulation can't exist(direct/ indirect)
39. In a hydrostatic and stably stratified atmosphere, -----energy is proportional to----  
-----energy.
40. In a stably stratified PBL, turbulent transfer is parameterized using -----
41. In the Ekman layer, major forces are pressure gradient force, Coriolis force and-----  
.
42. Internal gravity wave is a \_\_\_\_\_ wave.
43. Kelvin wave is \_\_\_\_\_ propagating wave.
44. Lowermost part of PBL is known as \_\_\_\_\_ (Ekman layer/Viscous sub-layer)
45. Mathematical expression for circulation is -----
46. Mechanical turbulence is maintained by \_\_\_\_\_ in TKE (Total Kinetic Energy) equation.
47. Mixing length theory is applicable to \_\_\_\_\_ stratified atmospheric PBL.
48. Monsoon trough is a region of \_\_\_\_\_ instability.
49. Mountain wave is an example of \_\_\_\_\_ gravity wave.
50. Net \_\_\_\_\_ across the base of an air column results in fall of pressure at center of the base (updraft/downdraft).
51. Net divergence in an atmospheric column above a point results in \_\_\_\_\_.
52. Net upward motion results into .....of potential energy.

53. Net vertically integrated \_\_\_\_\_ in a column over a point leads to fall of pressure at that point (lateral divergence/ positive density advection)
54. Net vertically integrated lateral advection of density in a column over a point leads to \_\_\_\_\_ of pressure at that point.
55. North east, south west oriented troughs in westerly mean flow transports angular momentum \_\_\_\_\_ ward.
56. Perturbation technique is applicable for-----amplitude theory.
57. Perturbation technique eliminates \_\_\_\_\_ terms from governing equation.
58. Rossby wave is a \_\_\_\_\_ wave.
59. Sea/Land breeze to occur, there must exist \_\_\_\_\_ in the atmosphere.
60. Sinking motion at a point gives rise to ----- of pressure there.
61. Stretching of vortex results in \_\_\_\_\_ in cyclonic vorticity.
62. The rate at which energy is being transported by a wave is known as -----.
63. Thermally direct circulation occurs in a \_\_\_\_\_ atmosphere (Barotropic/Baroclinic)
64. Top most sub layer in the viscous sub layer of PBL is called \_\_\_\_\_.
65. Tropics \_\_\_\_\_ angular momentum due to friction.
66. Tropics gain angular momentum due to-----torque.
67. Tropics loss zonal angular momentum due to \_\_\_\_\_.
68. Tsunami is an example of \_\_\_\_\_ wave.
69. Ultra-long Rossby wave is-----
70. uppermost part of PBL is known as \_\_\_\_\_ (Ekman layer/Viscous sub-layer)
71. Vorticity is a \_\_\_\_\_ quantity (scalar/vector)
72. Wave number of a wave is inversely proportional to the ----- of wave.

**Q.2 State with brief reasons whether following are true or false**

1. A zonally geostrophic mean flow with cyclonic vorticity is inertially stable.
2. A circular isobaric system moves in a westerly (east ward) direction.
3. A sinusoidal isobaric system moves in a westerly (east ward) direction.
4. A sub adiabatic lapse rate in PBL favors convective turbulence.
5. A sub adiabatic lapse rate in PBL favors mechanical turbulence.
6. A zonal mean flow with anticyclonic vorticity is inertially stable.
7. A zonal mean flow with cyclonic vorticity is inertially unstable.

8. Absolute circulation remains conserved in a frictionless baroclinic atmosphere.
9. Advection of relative vorticity and planetary vorticity have same effect on the movement of a westerly trough.
10. Ageostrophic wind is solely responsible for vertical motion.
11. Ahead of upper air westerly trough, high pressure area forms at surface
12. Any amount of baroclinicity doesn't always ensure baroclinic instability.
13. Baroclinicity has no role in the change of circulation.
14. Baroclinicity of the atmosphere has no role in the change of vorticity.
15. Barotropic instability is an example of static instability.
16. Belt of subtropical anticyclone / high pressure area is the source of horizontal kinetic energy.
17. Belt of subtropical anticyclone is the sink of Kinetic energy.
18. Circulation is a scalar quantity.
19. CISK results from mutual competitive interaction between synoptic scale lowlevel moisture convergence and cumulus scale latent heating.
20. Conversion from internal energy to kinetic energy is due to divergent circulation.
21. Divergent circulation is maintained by conversion of KE to IE.
22. Ekman layer pumping results spin down of primary circulation.
23. Equator ward moving low pressure system gains cyclonic circulation.
24. Equatorial convergence zone is the source of K.E.
25. Equatorial region is the sink of internal energy.
26. Fast moving waves are low frequency waves.
27. For a dispersive wave, phase velocity and group velocity are different.
28. For a non-divergent circulation  $C(I,K)=0$ .
29. For a one-dimensional dispersive wave frequency is proportional to wave number.
30. Genesis of cyclonic vortex over BOB during SWM season is mainly due to barotropic instability.
31. Genesis of lows over Head Bay of Bengal during S-W monsoon season, is mainly due to barotropic instability.
32. Global potential energy increases due to net downdraft of air.
33. Global warming may reduce the global internal energy.
34. Horizontal convergence results into reduction in cyclonic vorticity.
35. If a cyclonic circulation moves equator ward, then it gains cyclonic circulation
36. IGW is a non-dispersive wave.

37. In a barotropic atmosphere APE is zero.
38. In a barotropic atmosphere, Solenoidal term of vorticity equation vanishes.
39. In a convective boundary layer  $\Theta_e$  increases with height.
40. In a frictionless barotropic flow absolute circulation remains conserved.
41. In a non-divergent flow, it is not possible to convert Internal energy to Kinetic energy.
42. In any wind regime mountain torque and frictional torque have the same effect in global angular momentum budget.
43. In the atmospheric Ekman layer mean horizontal wind veers with height.
44. In westerly belt mountain torque and frictional torque have the same effect towards change in global angular momentum budget.
45. Internal gravity wave is a non-dispersive wave.
46. Internal gravity wave transports momentum and energy in the same direction.
47. K-theory is applicable to parameterize a stably stratified PBL.
48. Mean horizontal wind backs with height in Ekman layer.
49. Mechanical production term can never be negative.
50. Mechanical production term in TKE equation is always negative.
51. Mid-latitude belts gain westerly angular momentum due to mountain torque effect.
52. Mixing length in PBL is analogous to mean free path in kinetic theory of gas
53. Mixing length theory is applicable for stably stratified PBL only.
54. Monsoon trough is a region of barotropic instability.
55. Mountain and friction have same effects on angular momentum budget .
56. Mountain wave is a non-dispersive wave.
57. NE-SW oriented troughs in mid latitude westerly transports momentum equatorward.
58. NE-SW oriented troughs in westerly mean flow transports angular momentum poleward.
59. NE-SW oriented westerly trough transports angular momentum poleward.
60. Net vertically integrated lateral divergence across the side wall of an air column above a point cause rise of pressure there.
61. Net vertically integrated lateral divergence across the side wall of an air column above a point cause rise of pressure there.
62. NW-SE oriented troughs in mid latitude westerly transports momentum equatorward.
63. Perturbation technique is applicable for large amplitude disturbances.
64. Phase speed of wave is directly proportional to the wavelength of a wave.
65. Pole ward moving low pressure system gains cyclonic circulation.

66. Primary circulation and secondary circulation have same sense of rotation.
67. Progressive Rossby waves are of longer wave length.
68. Retrogressive Rossby waves are of longer wave length.
69. Rossby wave is a non-dispersive wave.
70. Rossby wave retrogrades with respect to westerly mean flow.
71. Rossby waves with wave length shorter than critical wave length retrogrades.
72. Secondary circulation causes spin down.
73. Source of global atmospheric internal energy is solar heating.
74. Static stability doesn't play any role in stabilizing unstable baroclinic waves in westerly.
75. Static stability doesn't play any role in the baroclinic instability.
76. The angle between isobar and isotherms gives a qualitatively measure of baroclinicity of the atmosphere.
77. Tilting or tipping has no role in the change of circulation
78. Tropics gain westerly angular momentum due to mountain torque effect.
79. Vertical shear of horizontal wind favors convective turbulence in a stably stratified PBL.

### **Q.3 Answer following questions**

1. "Sun is the source of all atmospheric energy" – Justify the statement. Discuss how in a stably stratified and hydrostatic atmosphere, internal energy is proportional to potential energy. Discuss about available potential energy.
2. Define atmospheric energetics. Write down the expression for global internal energy, global potential energy and global kinetic energy.
3. Define barotropic instability. Discuss the necessary condition for a mean flow to be barotropic ally unstable. "Genesis of cyclonic vortices overhead bay during southwest monsoon season is mainly due to barotropic instability.
4. Define circulation. Write down Bjerknes's circulation theorem. Using this theorem explain the role of tipping effect in the change of circulation.
5. Define circulation. Write down Bjerknes circulation theorem. Discuss how this theorem can be used to explain the effect of latitudinal change on the change in circulation.
6. Define circulation. Write down Kelvin's circulation theorem. Discuss how this theorem can be used to explain Hadley circulation.

7. Define gravity wave. Discuss the categorization of gravity wave. Discuss in brief the dispersion property of any one of them.
8. Define gravity wave. Discuss about their classification. Discuss in brief about salient features of internal gravity wave.
9. Define hydrodynamic instability. Discuss the categorization of hydrodynamic instability. Discuss in brief the inertial instability.
10. Define Hydrodynamic instability. Discuss the categorization of hydrodynamic instability. Discuss in brief any one of them.
11. Define Hydrodynamic instability. Discuss classification of the same. Discuss the necessary condition for inertial instability.
12. Define Hydrodynamic instability. Discuss in detail about their classification. Discuss in detail about any one of such instabilities.
13. Define hydrodynamical instability. Discuss categorization of hydrodynamic instability.
14. Define PBL. Mention different sub layers in PBL. What are different types of turbulent motion exist in PBL?
15. Write down TKE equation. Discuss in brief BPL and MP terms.
16. Define Phase velocity and group velocity of a wave. When a wave is said to be dispersive ? Discuss in brief about the salient features of Rossby wave.
17. Define wave number, group velocity and phase speed of any wave.
18. Define wave number, phase velocity and group velocity of an atmospheric wave. Write down their expressions.
19. Discuss about the movement of very long and very short Rossby wave.
20. Discuss classification of gravity waves. Write down the dispersion relation for internal gravity wave (IGW). Hence discuss the vertical momentum and energy propagation of IGW for different combinations of horizontal ( $k$ ) and vertical ( $m$ ) wave number.
21. Discuss in brief the baroclinic instability.
22. Discuss in brief the mechanisms of conversions among different forms of energy.
23. Discuss in detail about the conversion mechanisms among themselves. "Belt of subtropical anticyclone is source of horizontal kinetic energy" – Justify the statement.
24. Discuss the concept of Quasi-geostrophy. What is  $\beta$  Plane and its significance? Write down the quasi-geostrophic vorticity equation. Discuss in detail the physical interpretation of different terms.



25. Discuss the dispersion relation of Rossby wave.
26. Show that in a hydrostatically stable and stably stratified atmosphere P.E.  $\propto$  I.E.  
Discuss in brief about the concept of Available Potential Energy.
27. Show that in a hydrostatically stable and stably stratified atmosphere global internal energy is proportional to global potential energy. Hence, discuss in short about available potential energy.
28. What is energetics? Mention different forms of energies, governing atmospheric flow.  
Write down their expression.
29. Write down expression for vertical profile of horizontal wind in Ekman layer. Obtain an expression for depth of Ekman layer. Explain secondary circulation and spin down.
30. Write down vorticity equation. Discuss the divergence and tilting terms in detail using suitable diagrams. Using divergence term explain why ahead of an upper air (stationary) westerly trough upper air divergence takes place.
31. Write down global angular momentum budget equation. Discuss in detail the physical interpretation of different terms.
32. Write down global kinetic energy, internal energy and global potential energy equations.
33. Write down pressure tendency equation. Discuss different mechanisms for change of pressure at a point.
34. Write down the angular momentum budget equation. Discuss in detail different atmospheric processes responsible for change in global angular momentum.
35. Write down the expression for global kinetic energy, Internal energy and potential energy. Discuss in brief their budget.
36. Write down the expression for mean wind in atmospheric Ekman layer. Obtain the depth of Ekman layer. Discuss in brief Ekman layer pumping, Secondary circulation and spin down.
37. Write down the vertical profile for mean horizontal wind in the Ekman layer of atmospheric boundary layer. Obtain the depth of Ekman layer. Discuss secondary circulation and spin down.
38. Write down turbulent K.E equation. Discuss the physical interpretation of Different terms.
39. Write down turbulent kinetic energy equation. Discuss in brief about the physical interpretation of BPL and MP term. Define flux Richardson number.

40. Write down turbulent kinetic energy equation. Discuss in detail the BPL and MP terms.
41. Write down vorticity equation. Discuss physical interpretation of any two terms. Discuss dynamically the formation of surface low pressure area ahead of a westerly trough.
42. Write down vorticity equation. Using schematic diagram, discuss in detail about the physical interpretation of solenoidal term.

**Q.4 Write short notes on any two of the following:**

1. Barotropic instability
2. CISK
3. Ekman layer
4. Gravity wave
5. Hydro dynamic instability definition and categorization
6. Internal gravity wave
7. Kelvin wave
8. Meridional transport of Global angular momentum.
9. Mixing length theory
10. Mountain torque effect on global angular momentum budget.
11. Perturbation technique
12. Perturbation theory.
13. Rossby wave
14. Turbulent kinetic energy equation.