National University of Lesotho

BSc and BSc Ed. Supplementary Examination

PG 2411 – Introduction to Atmospheric Science

August, 2023 **Marks: 100** **3 Hours**

Instruction:

Answer any **four (4)** questions

Question 1

a) A small parcel of air has a temperature of 20 ^{o}C and a pressure of 1013.25 mb. Calculate the density and the specific volume of the parcel. (6)
b) What would be the new temperature of the air parcel if it were lifted 2 km above sea level at a lapse rate of 6.5 ^{o}C per km? (4)
c) Explain the conditions for the **three (3)** types of atmospheric instability/stability. (10)
d) How can a stable atmosphere become unstable? (5)

Question 2

Interpret or explain the following in light of the principles covered in the course:

a) Globally averaged surface pressure is 28 hPa lower than globally averaged sea level pressure (1013 hPa). (5)
b) Runways are longer at high altitude airports and stricter weight limits are imposed on aircraft taking off on hot summer days. (5)
c) To carry a given load, a hot air balloon cruising at a high altitude needs to be bigger or hotter than a balloon cruising at a lower altitude. (5)
d) More fuel is required to lift a hot air balloon through an inversion layer than to lift it through a layer of the same thickness that exhibits a steep temperature lapse rate. Other conditions being the same, more fuel is required to operate a hot air balloon on a hot day than a cold day. (5)
e) Aircraft landings on summer afternoons tend to be bumpier than nighttime landings, especially on clear days. (5)

Question 3

a) Calculate the thickness between the 1000 and 500 hPa levels for an isothermal atmosphere if the surface temperature is 27 ^{o}C. How would the thickness be compared to the case where the atmosphere was non-isothermal (lapse conditions)? (9)
b) Calculate the thickness of the layer between the 1000 and 500 hPa pressure surfaces
    i. At a point in the tropics where the mean temperature of the layer is 15 ^{o}C. (4)

ii. At a point in the polar regions where the corresponding mean temperature is -40 ^{o}C (4)

c) In a sounding taken on a typical winter day at the South Pole the temperature at the ground is -50 ^{o}C and the temperature at the top of a 30 m high tower is -80 ^{o}C. Estimate the lapse rate within the lowest 30 m, expressed in ^{o}CKm^{-1}. (8)

Question 4

a) Calculate the geostrophic wind speed if the pressure changes by 3.1 kPa over 1050 km at latitude 65^{o} and a height of 7 km in the atmosphere. At this height, air density is about 0.6 kg/m^{3}. (5)

b) At the same latitude, the height of the 500 hPa surface increases by 30 m over 200 km. Calculate the geostrophic wind speed in this case. (5)

c) What determines the magnitude and direction of the pressure gradient force? (5)

d) For a geostrophic wind speed of 14m/s, a radius of curvature of 1500 km, and Coriolis parameter f_c of 7 x 10^{-5} s^{-1}, calculate

i. The gradient wind speed for a cyclone (5)

ii. The gradient wind speed for an anticyclone. (5)

Question 5

a) Using the hydrostatic equation and the ideal gas law derive an expression for the variation of pressure with height. (10)

b) The earth-atmosphere system as a whole is said to be in a state of radiative equilibrium with the sun and this does not extend to all parts of the earth, why is this the case? (15)

Question 6

a) Write down the units using only kg, m, and se of the following:

i. Joule (3)

ii. Newton (3)

iii. Pascal (3)

iv. Velocity (3)

v. Acceleration (3)

b) The pilot of an aircraft flying from Miami to Montreal in winter wishes to know the air density for takeoff at the two terminals. At Miami the surface pressure is 1000 hPa and the temperature is 30^{o}C. At Montreal the surface pressure is 1040 hPa and the temperature is -20^{o}C. At what temperature over Montreal would the density be the same as at Miami. (5)

c) A meteorological station is located 100 m below sea level. If the surface pressure at this station is 1045 hPa, the temperature at the surface is 20 ^{o}C, and the mean temperature for the 1000 to 500 hPa layer is -2 ^{o}C, compute the height of the 500 hPa pressure level above the meteorological station. (5)