Venue : IV LT 1

Date : 21 NOV. 2008 (Fri.)

MAJOR EXAM

ASL 703 Physics of Atmosphere & Ocean

Max. Mark: 25

Time : 10.30-12.30

1. Is there a significant difference between dry adiabatic and moist unsaturated adiabatic processes? Substantiate your answer based on the following: (1)

   (i) Using the Poisson's equation, establish a mathematical relationship between the values of constant κ ($= R/c_p$) valid for dry and unsaturated air. (3)

   (ii) Compare the values of the potential temperature of a parcel of air with temperature 10°C and pressure 700 hPa when it is perfectly dry and when it has a mixing ratio of 6 gm/kg. (3)

2. (i) The equation of state in the differential form is given as (3)

$$\frac{1}{\rho} d\rho = \gamma_T dp - \alpha_T dT$$

then obtain the expressions for γ_T and α_T if $p = \rho R T$. Also write the equation of state for seawater in the differential form.

   (ii) A hot meteorite falls (velocity 200 km/hr) into the Indian Ocean. (3) The meteorite was originally at 1000°C, weighs 1 kg, and has a heat capacity of 0.82 J/g/K. If the ocean temperature is 15°C, calculate the change in entropy of the universe as a result of this event.

3. (i) A parcel of water is added to the ocean surface that is heavier than any water in the ocean. Suppose the parcel sinks to the ocean bottom, then estimate the change in temperature the parcel undergoes, and state explicitly the assumption you make. (3)

   (ii) Consider the development of a simplified, convective, oceanic mixed layer in winter. Initially at the start of winter, the temperature profile is given by $T(z) = T_s + \Lambda z$, where z is the depth (which is zero at the surface and increases upwards) and the gradient $\Lambda > 0$. During the winter, heat is lost from the surface at a rate Q W/m². As the surface cools, convection sets in and mixes the developing, cold, mixed layer of depth $h(t)$ which has a uniform temperature $T_m(t)$. Assume that the temperature is continuous across the base. By matching the heat lost through the surface to the changing heat content of the water column, determine how $h(t)$ and $T_m(t)$ evolve in time (t) over the winter period. Also assume the salinity effects negligible i.e. $\rho = \rho_{ref} [1 - \alpha_T (T - T_{ref})]$, $\rho_{ref} = 1000$ kg/m³, $T_{ref} = 283$ K, and $\alpha_T = 1.67 \times 10^{-4}$ K^{-1}. If $Q = 25$ W/m² and $\Lambda = 10$°C/km, how long will it take the mixed layer to reach a depth of 100 meters. Also give the growth of mixed layer per day. (3)

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4. (i) Consider a liquid sitting in a container with a free surface at the top ($z = H$). The liquid obeys the equation of state (3)

$$\rho = \rho_{ref}\left[1 - \alpha_T (T - T_{ref})\right]$$

with values of ρ_{ref}, α_T and T_{ref} as given in Q.3(ii). The internal energy (e) is given as $e = C_w T$, where C_w is the specific heat of water. Suppose the liquid is heated and its temperature rises by ΔT and the free surface rises by ΔH (small). Obtain an expression for the change in ~~de~~ & the change in the gravitational potential energy (GPE) of the ocean which is defined for a layer of density ρ and depth h by the integral

$$GPE = \int_0^h \rho g z \, dz$$

g is the acceleration due to gravity

Estimate also the average sea level rise due to thermal expansion of seawater if global warming increases the temperature of the ocean by 4K. Take ocean depth 5000 m in your calculations.

(ii) Calculate the evaporation flux (E) under the following conditions over a fresh water lake given as (3)

$$e_s = 6.11 \exp\left\{5417.04\left[\frac{1}{273} - \frac{1}{T_a}\right]\right\}, \quad q = \frac{\varepsilon e_s}{p - e_s}$$

$\varepsilon = 0.622$, $u_a = 5$ m/s, $q_a = 20$ g/kg, $T_a = 30°C$.

u_a is velocity of air stream, q_a its specific humidity at air temperature T_a. Also calculate the evaporation flux over the sea if $\rho_{sea} = 1026$ kg/m³ and $q_{sea} = 0.98q$, and the air flow has u_a, q_a, T_a as given above. Take the bulk aerodynamic formula

$$E = \rho_a C_E (u_a - u_0)(q_s - q_a)$$

u_0 = surface velocity

$$C_E = 1.5 \times 10^{-3} \text{ (non dimensional)}$$