※ 注意：請於試卷內之「非選擇題作答區」依序作答，並應註明作答之大題及小題題號。

1. As the air parcel being lifted, many important physical processes are involved. **The following question is about all the derivations in the course of atmospheric thermodynamics** that helps to describe the changes of the air parcel. **[20%]**

   (a) (5%) Regarding the potential temperature, please derive the mathematical expression of the potential temperature starting from the first law of thermodynamics.

   (b) (5%) During the phase change of water (vapor to liquid), assuming that it is in equilibrium, derive the Clausius-Clapeyron (C-C) equation for liquid-vapor phase changes.

   (c) (5%) Assume that the dependence of saturation specific humidity (q_{vs}) on pressure is small. Derive the temperature dependency for changes in q_{vs}.

   (d) (5%) With the help of (c), derive the pseudo-adiabatic temperature lapse rate in the following form. Specify the assumption used during the derivation.

$$\frac{dT}{dz} = -\frac{g}{C_p^*}$$

   where C_p^* is in the form of $C_p\left(1+\frac{L_v^2 q_s}{c_p R_v T^2}\right)$

   Given parameters: $\varepsilon = R_d/R_v$, $R_d = 287 Jkg^{-1}K^{-1}$, $R_v = 461.5 Jkg^{-1}K^{-1}$

   $c_p = 1005 Jkg^{-1}K^{-1}$, $c_V = 718 Jkg^{-1}K^{-1}$,

   $c_{water} = 4187 Jkg^{-1}K^{-1}$, $c_{ice} = 2050 Jkg^{-1}K^{-1}$

   $l_f = 3.33\times10^5 Jkg^{-1}$, $l_v = 2.50\times10^6 Jkg^{-1}$ $l_s = 2.83\times10^6 Jkg^{-1}$

   $\rho_w = 1000 kgm^{-3}$ (water) $\rho_i = 917 kgm^{-3}$ (ice), $\rho_v = 1.2 kgm^{-3}$ (vapor)

$$\ln\frac{e_s}{6.11} = \frac{l_v}{R_v}\left(\frac{1}{273}-\frac{1}{T}\right) = 19.85 - \frac{5418.7}{T}$$

$$e_s = A\exp^{-B/T}$$

$$A = 2.53\times10^8 kPa,\ B = 5.42\times10^3 K$$

$$e_{si} = A\exp^{-B/T}$$

$$A = 3.41\times10^9 kpa$$

$$B = 6.13\times10^3 K$$

2. (a) (5%) What is atmospheric window?
   (b) (5%) Can you find atmospheric window in both short wave and long wave channels?
   (c) (5%) If so, can you give examples?

3. (20%) When radiation passes through a medium,

$$\frac{dI_\lambda}{k_\lambda \rho ds} = -I_\lambda + J_\lambda$$

   the change of radiation is determined by?

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4. (5%) Consider $I_\nu^{\uparrow}(\tau,\mu) = B_\nu(\tau_*)T_\nu[(\tau_* - \tau)/\mu] - \int_\tau^{\tau_*} B_\nu(\tau')\frac{d}{d\tau'}T_\nu[(\tau' - \tau)/\mu]d\tau'$

   What is T_ν?

5. (a) (5%) Describe the principles of the Köhler theory.
   (b) (5%) How can the Köhler curve determine whether an aerosol particle can be activated into a cloud drop or not?
   (c) (5%) Discuss which factors influence the number concentration of cloud drops near the cloud base.

6. (a) (5%) What are the definitions of collision efficiency and coalescence efficiency?
   (b) (5%) Which processes caused the collision efficiency to be less than 1?
   (c) (5%) Which processes caused the coalescence efficiency to be less than 1?

7. (a) (5%) Which factors determine the primary and secondary growth habits (成長習性) of cloud ice crystals?
   (b) (5%) How does the growth habit influence the growth of ice crystals by vapor diffusion?

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