Constants or equations that you might need	
PV= nRT for all gases discussed in this test R (gas constant) = 8.314 J mol^{-1} K^{-1}, 0.082 dm^3 atm mol^{-1} K^{-1} k (Boltzmann constant) = 1.381 x 10^{-23} J K^{-1} h (Planck's constant) = 6.626 x 10^{-34} Js N_{av} = 6.02 x 10^{23} molecule mol^{-1} Pa = Nm^{-2}	1 atm = 760 Torr = 101300 Pa = 1013 hPa Scale height = 7.4 km The radius of the Earth : 6400 km 1 ppmv = 1 x 10^{-6} mol/mol 1 ppbv = 1 x 10^{-9} mol/mol 1 pptv = 1 x 10^{-12} mol/mol

1. Consider the observed temperature profile in Figure 1:

(a) (15 pts) Identify stable and unstable regions in the profile. Briefly explain. (hints: compare to the dry adiabatic lapse rate, 9.8 K km^{-1})

(b) (10 pts) Consider an air parcel rising from A to B and forming a cloud at point B. Assuming a wet adiabatic lapse rate Γ_w = 6 K km^{-1}, calculate the altitude to which the air parcel will rise before it becomes stable relative to the surrounding atmosphere.

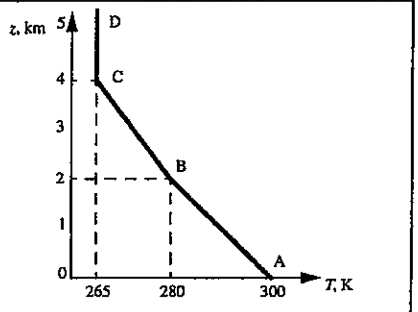

Figure 1 Vertical temperature profile

2. (10 pts) Aerosols and greenhouse gases can affect radiation on the Earth. Please describe how they affect radiation (both long and short wavelength light) respectively and briefly.

3. Consider the following typical vertical profile of ozone (O_3) number densities measured over Taiwan in Figure 3.

(a) (10 pts) please describe how the ozone is produced over the stratosphere (10-50 km altitude) briefly.

(b) (10 pts) please describe how the ozone is produced chemically over the troposphere briefly.

(c) (10 pts) please describe the impacts (影響) of the ozone over the troposphere and the stratosphere respectively.

(d) (10 pts) Calculate the mixing ratio of O_3 at the peak of the O_3 layer (z = 25 km; P = 35 hPa; T = 220 K).

(e) (15 pts) The total number of O_3 molecules per unit area of Earth surface is called the O_3 column and determines the efficiency with which the O_3 layer prevents solar UV radiation from reaching the Earth's surface. Estimate the O_3 column in the above profile by approximating the profile with the piecewise linear function shown as the thin solid line.

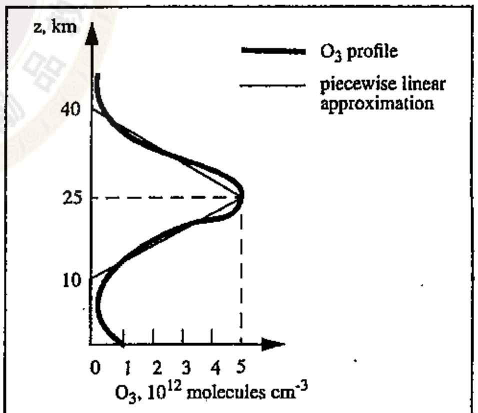

Figure 3 Vertical ozone profile.

4. (10 pts) The rate of exchange of air between the troposphere and the stratosphere is critical for determining the potential of various pollutants emitted from the surface to reach the stratosphere and affect the stratospheric ozone layer. One of the first estimates of this rate was made in the 1960s using measurements of radiative isotope, strontium-90 (^{90}Sr) in the stratosphere. Assuming that transfer of ^{90}Sr from the troposphere to the stratosphere is negligible, the residence time of air in the stratosphere is $\tau_S = 1/k_{ST}$ = 1.3 years. **Please use the two-box model as shown in Figure 4 to estimate the residence time ($1/k_{TS}$) of air in the troposphere** (hints: mass balance equations for two boxes).

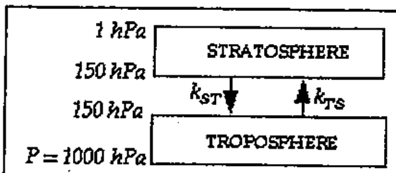

Figure 4 Two-box model for stratosphere-troposphere exchange