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SIO 217a Atmospheric and Climate Sciences I: Atmospheric Thermodynamics

Fall 2012 Final Exam (No calculators, notes, books, PDAs.)

Curry and Webster, Ch. 1-8, 12, 13

Here are some numerical values, some of which may be useful on this exam:
Average radius of Earth: 6370 km
Mean reflectivity of the Earth: 0.31
Mean molecular weight of dry air: 29 g/mole
Mean molecular weight of water vapor: 18 g/mole
Gas constant for dry air, $\boldsymbol{R_d}$: 287 J deg^{-1} kg^{-1}
Gas constant for water vapor, $\boldsymbol{R_v}$: 461 J deg^{-1} kg^{-1}
Specific heat at constant pressure, $\boldsymbol{c_p}$: 1004 J deg^{-1} kg^{-1}
Specific heat at constant volume, $\boldsymbol{c_v}$: 717 J deg^{-1} kg^{-1}
Latent heat of vaporization for water at 273K, $\boldsymbol{L_{lv}}$: 2.50×10^{6} J kg^{-1}
Latent heat of vaporization for water at 293K, $\boldsymbol{L_{lv}}$: 2.45×10^{6} J kg^{-1}
Solar luminosity: 3.92×10^{26} W
Earth-sun distance: 1.50×10^{11} m
Stefan-Boltzmann constant, $\boldsymbol{\sigma}$: 5.67×10^{-8} W m^{-2} K^{-4}

1. **Köhler Curve Question (15 pts):** An article in *Science* (Dusek et al., 2006) was entitled "Size matters more than chemistry for cloud-nucleating ability of aerosol particles." Explain the roles of particle size and chemical composition in nucleating cloud droplets and include an illustrative particle size distribution. Name and state any relevant theories. Based on Köhler theory (1921), do you think the findings of this recent article are likely (based on the title) to be sufficiently original to merit publication in *Science*?

2. **Definitions Question (10 pts):** Define the following terms in 10 words or less; an equation, graph, or sketch may be added if appropriate:
   a. radiative equilibrium
   b. absorptivity
   c. hydrostatic balance
   d. conditionally stable
   e. isentropic

3. **Term Project Question (10 pts)**: Answer <u>TWO</u> of the following questions.
   a) How does the initial relative humidity change the lifting condensation level?
   b) How does the stability of the lapse rate change the lifting condensation level?
   c) How does a temperature inversion change the parcel mixing height?
   d) How does the entrainment of dry air affect the parcel mixing height?

4. **CAPE Question (15 pts):** Answer each part below. State the assumptions of your approach.
   a. State how to calculate the maximum updraft velocity of a dry air parcel from CAPE.
   b. How does water vapor change this result? Explain why.
   c. How does liquid water change this result? Explain why.

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5. **Clausius Clapeyron Question (15 pts):** A local company has proposed to produce freshwater from the water vapor in ambient air at Point Loma. Assume the air at their Point Loma site is 30°C and 100% RH. The saturation vapor pressure (of water) at a temperature of 30°C is 42 hPa. Then they cool the air using passive geothermal cooling to 10°C. (Assume that no water actually freezes, so that you remain just above freezing throughout.) State how you would find the values below <u>from the information provided in this exam</u> for the air (after this cooling), including any laws, equations, and assumptions used, and simplifying as much as possible:
   a. saturation vapor pressure (of water) at 10°C.
   b. relative humidity.
   c. specific humidity
   d. mixing ratio
   e. virtual temperature
   f. the amount of water expected to condense to liquid for each kg of air cooled.

6. **Earth Radiation Balance Question (20 pts):** Almost one-third of the Earth's incoming solar radiation is reflected back to space.
   a. Name the property of the Earth controls the fraction of incoming light reflected.
   b. Calculate the amount of incoming solar radiation at the top of the atmosphere [in W m^{-2}].
   c. What happens to the energy from the incoming radiation that is not reflected?
   d. If the amount of light reflected were *decreased*, how would a simple model *with a greenhouse effect* predict Earth's temperature would respond? Give your model and state its assumptions.

7. **Climate Feedback Question (15 pts)**
   a. What is the difference between a positive and negative feedback?
   b. Give an example of a positive feedback in the Earth system and explain its importance.
   c. Give an example of a negative feedback in the Earth system and explain its importance.